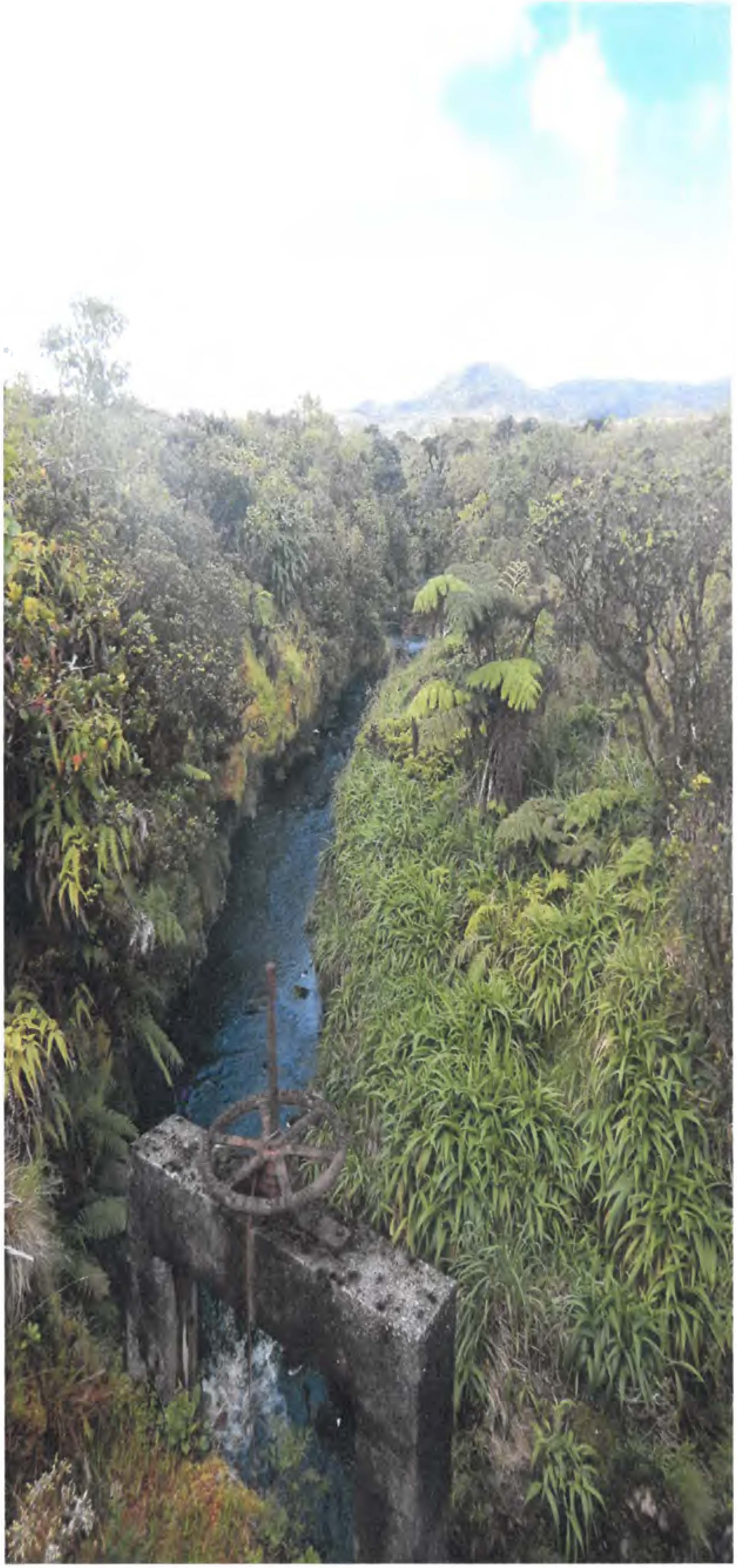

AGRICULTURAL WATER USE AND DEVELOPMENT PLAN UPDATE

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

December 2019

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AGRICULTURAL WATER USE AND DEVELOPMENT PLAN UPDATE

December 2019

Prepared for:

State of Hawai'i
Department of Agriculture
Agricultural Resource Management Division

Prepared by:

EKNA Services, Inc.

ACKNOWLEDGMENT

The authors would like to thank the farmers, ranchers, irrigation system managers and representatives, and other agriculture stakeholders for their time, effort, interviews, and discussions on various agricultural water topics. These interviews and discussions provided valuable input and information on topics such as agricultural water use, issues and concerns, and irrigation systems. Without these hardworking individuals, the agricultural industry would not survive, and sustainability would not be possible.

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LIST OF ACRONYMS

A&B	Alexander & Baldwin
ALISH	Agricultural Lands of Importance to the State of Hawai'i
ADC	State of Hawai'i, Agricultural Development Corporation
ARMD	Agricultural Resource Management Division
AWUDP	Agricultural Water Use and Development Plan
BMP	Best Management Practices
CIP	Capital Improvement Program
CMP	Corrugated Metal Pipe
CRM	Concrete Rock Masonry
CWRM	DLNR Commission on Water Resources Management
DBEDT	State of Hawai'i, Department of Business, Economic Development and Tourism
DHHL	State of Hawai'i, Department of Hawaiian Home Lands
DI	Ductile Iron
DLNR	State of Hawai'i, Department of Land and Natural Resources
EKIS	East Kaua'i Irrigation System
EMI	East Maui Irrigation System
FOB	Free-on-board
GGT	George Galbraith Trust
GIS	Geographical Information System
GLIS	Galbraith Lands Irrigation System
gpd	Gallons per day
gpd/acre	Gallons per day per acre
GPS	Global Positioning System
HASS	Hawai'i Agricultural Statistics
HC&S	Hawaiian Commercial & Sugar Company
HDOA	State of Hawai'i Department of Agriculture
HDPE	High-density polyethylene plastic

HHFDC	Hawai'i Housing Finance and Development Corporation
HRS	Hawai'i Revised Statutes
IAL	Important Agricultural Lands
IIFS	Interim Instream Flow Standards
IWREDSS	Irrigation Water Requirement Estimation Decision Support System
KEDIS	Kekaha Ditch Irrigation System
KODIS	Kōke'e Ditch Irrigation System
KSBE	Kamehameha School Bishop Estate
KSWRS	Kula Stormwater Reclamation Study
LCC	Land Capability Classification
LF	Linear Feet
LHD	Lower Hāmākua Ditch
MG	Million gallons
MGD	Million gallons per day
MG/yr	Million gallons per year
MIS	Moloka'i Irrigation System
NASS	USDA National Agricultural Service Statistics
NRCS	National Resources Conservation Service
SCADA	Supervisory Control and Data Acquisition
UHD	Upper Hāmākua Ditch
USDA	United States of America Department of Agriculture
USGS	United States of America Geological Survey
WDIS	Waiāhole Ditch Irrigation System
WIS	Waimānalo Irrigation System or Waimea Irrigation System
WMA	Water Management Area
WUP	Water Use Permit
WWTP	Wahiawā Wastewater Treatment Plant

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EXECUTIVE SUMMARY

The essential need for water to grow crops and maintain a viable agricultural industry led to legislation to prepare an Agricultural Water Use and Development Plan (AWUDP). The State of Hawai'i, Department of Agriculture published the original AWUDP in December 2003, revised December 2004.

This document is an update to the 2004 AWUDP. This AWUDP Update is a culmination of research of past studies, scientific data, publicly available information, onsite inspections, and interviews with water system managers and farmers throughout the state.

The objectives for this AWUDP Update are as follows:

- Meet the requirements of Hawai'i Revised Statutes 174C-31e;
- Inventory water systems not inventoried in the 2004 AWUDP;
- Update agriculture planning water demand rate and water demand forecasts; and
- Propose a five-year program to repair the systems and set up a long-range plan to manage the systems.

Inventory

This AWUDP Update includes an inventory of water systems that were not examined in the 2004 AWUDP (shown in Table ES-1). The inventory provides information and maps of the agricultural water systems, including system alignments and components, agricultural potential, land use (crop categories), Important Agricultural Lands, condition of the systems, and proposed improvements, if applicable. This study found most of the agricultural water systems in use, and in relatively good or fair condition. Limited portions of systems found to be in poor condition have the potential to be rehabilitated with additional resources.

This document also updates the status of systems inventoried in the 2004 AWUDP (Table ES-1) and associated capital improvements. These water systems are still in use, and various capital improvement projects have since been completed. Additional capital improvement projects are underway.

Table ES-1
Hawai'i Agricultural Water Systems Reviewed for the AWUDP Update and 2004 AWUDP

AWUDP Update	2004 AWUDP
Kaua'i - Kaloko and Pu'u Ka Ele Ditches - Stone Dam and Kalihiwai Irrigation Subsystems - Anahola Ditch - Upper and Lower Līhu'e Ditches and portion of Waiahi-'Ili'ili'ula Ditch - Upper and Lower Ha'ikū Ditches - Wai'aha-Ku'ia Aqueduct, por. Waiahi-'Ili'ili'ula Ditch, and Kōloa-Wilcox Ditch - Olokele Ditch O'ahu - O'ahu Ditch (Wahiawā, Helemano, Tanaka, and Ito Ditches) - 'Ōpae'ula, and Kamananui Ditches - Kahuku Irrigation System - Galbraith Lands Irrigation System Hawai'i - Ka'ū Agribusiness Irrigation System - Kohala Ditch - Kehena Ditch	Kaua'i - East Kaua'i Irrigation System - Kekaha Ditch Irrigation System - Kōke'e Ditch Irrigation System - Kaua'i Coffee Irrigation System O'ahu - Waiāhole Ditch Irrigation System - Waimānalo Irrigation System Molokai - Moloka'i Irrigation System Maui - Maui Land and Pineapple/Pioneer Mill Irrigation System - East Maui Irrigation System - West Maui Irrigation System - Upcountry Maui Irrigation System Hawai'i - Lower Hāmākua Ditch Irrigation System - Waimea Irrigation System

2014 Farmer Survey

The cost of water, other farm inputs, and availability of labor all affect the economic viability of Hawai'i's agriculture industry, especially when competing with cheaper imports and foreign commodities in state and offshore markets. The underlying sentiment expressed by system managers and farmers during the development of this AWUDP is the importance of keeping water systems and flow at current levels to maintain or increase agricultural production.

Several agricultural areas are restricted from fully utilizing the available land area due to lack of water or prohibitive water costs. During the development of this plan, farmers suggested several areas where additional water resources could potentially increase diversified agriculture and use of irrigated pastures. These areas are within the North and South Kohala regions of Hawai'i and the lower and upper Kula areas of Maui. The development plan recommends funding for initial studies of these potential systems to determine feasibility, development cost, stakeholders, and management.

Recommended Water Demand Rates

Planning for agricultural water demand is key to reserving enough water to sustain and grow the agricultural industry. For planning purposes this AWUDP Update reevaluates the water demand rate. The 2004 AWUDP found the water demand rate to be 3,400 gallons per day per acre, based on an analysis of actual metered water demand from one growing area. This AWUDP Update expands on this analysis by evaluating water demand from 113 farms growing different crops in various growing regions throughout the state; water demand rates from farms in Kunia, O'ahu; and published historical demand rates. Based on this evaluation, the planning-level agricultural water demand rates at the farm-level water meter are as follows:

- 3,900 gpd/acre for diversified agriculture, for usable acreage that is 50 percent planted (average condition);
- 7,800 gpd/acre for diversified agriculture, for usable acreage that is 100 percent planted;
- 8,100 gpd/acre for diversified agriculture, for usable acreage that is 50 percent planted, under drought conditions or in dry areas;
- 16,200 gpd/acre for diversified agriculture for usable acreage that is 100 percent planted, under drought or dry conditions; and
- 8,000 gpd/acre or more for irrigated pastures (usable acreage that is 100 percent planted.

These water demand rates are for statewide planning for agricultural water demand. If a specific site is being studied, a site-specific water demand analysis should be completed.

Forecast

This AWUDP Update develops new forecasts for water demand. As most of the existing agricultural water systems are or will soon be over a hundred years old, future water delivery will be significantly influenced by these systems' condition and ability to provide water. To address the vulnerability and reliance on these systems, forecasts are based on capital investment into the agricultural water systems for maintenance and improvement. Therefore, the forecast has three scenarios: 1) no-action, 2) continued maintenance, and 3) increased capital investment. The water demand at the planning horizon is as follows.

- No-action scenario. The no-action scenario assumes that no resources are used to maintain or upgrade the system. Water flow in the system will shut down due to a failure in the water system. At the planning horizon, the forecast water demand will be zero (0) million gallons per day, and agricultural production will significantly decrease.

- Continued maintenance. The continued maintenance scenario assumes that resources are available to maintain the current system and will be able to meet the forecast agricultural farm value growth rate. The forecast agricultural farm value growth rate is based on historical trend analysis and is less than one percent (1%) per year. Therefore, the forecast water demand in this scenario is estimated to be 734 million gallons per day by 2035.

- Increased capital investment. The increased capital investment scenario, or high forecast, assumes greater agricultural production to assist the state in achieving policies such as sustainability, self-sufficiency, and import replacement. In addition, water systems need to be resilient to the impacts of climate change, as espoused in the smart and resilient city concepts. The forecast water demand in this scenario is estimated to be 1,170 million gallons per day by 2035.

Development Plan

The development plan includes proposed maintenance and capital improvement projects for continued use of the studied irrigation systems (continued maintenance scenario). To maintain the current systems and conduct initial studies for expanded water systems, the cost is estimated to be 167.5 million dollars (2018 dollars) for the first five years.

The development plan also includes potential long-range strategies for system management. Details for long-term investment will not be determined until initial maintenance and capital improvement projects are completed.

Conclusion

Agriculture is an essential component for the state to achieve its goals of sustainability and a diversified economy. The agricultural industry relies on these water systems to deliver inexpensive water to meet and expand agricultural production in normal and drought conditions. By supporting, maintaining, improving, and expanding these water systems, farmers have the potential to maximize the use of agricultural lands and produce agricultural commodities to meet state and export market demands.

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CHAPTER 1
INTRODUCTION

The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency, and assure the availability of agriculturally suitable lands.
State Constitution

In the late 1990s, the transition of ownership and management of the plantation water systems to other entities, including the State of Hawai'i, was increasing. To protect the water systems affected by plantation closures, the State of Hawai'i legislature and Governor Benjamin Cayetano enacted Act 101 in 1998, which became Hawai'i Revised Statutes (HRS) Chapter 174C-31(e). The HRS 174C-31(e) created the objectives of the Agricultural Water Use and Development Plan (AWUDP) and directs the Commission on Water Resource Management (CWRM) to include the AWUDP in the Hawai'i State Water Projects Plan. The statute states that the State of Hawai'i, Department of Agriculture (HDOA) shall prepare a master irrigation inventory plan to cover the following topics.

- Inventory public and private irrigation water systems.
- Identify the extent of rehabilitation needed for each system.
- Identify source(s) of water used by agricultural operations, particularly those on lands identified and designated as important agricultural land under part III of chapter 205.
- Identify current and future water needs for agricultural operations, particularly those on land identified and designated as important agricultural lands under part III of chapter 205.
- Subsidize the cost of repair and maintenance of the systems.
- Establish criteria to prioritize the rehabilitation of the systems.
- Develop a five-year program to repair the systems.
- Set up a long-range plan to manage the systems.

The AWUDP is intended for inclusion in the state's Water Projects Plan by CWRM. In 2000, CWRM developed a set of guidelines for the AWUDP, titled the *Statewide Framework for Updating the Hawai'i Water Plan* (Framework). The Framework is provided in Appendix B, and the objective of the AWUDP in the Framework is stated below.

> ***Agricultural Water Use and Development Plan (AWUDP)***
> *The major objective of the AWUDP is to develop a long-range management plan that assesses state and private agricultural water use, supply, and irrigation water systems.*
>
> *The plan shall address projected water demands and prioritized rehabilitation of existing agricultural water systems.*

1.1 2004 AGRICULTURAL WATER USE AND DEVELOPMENT PLAN

The 2004 AWUDP was developed as an initial document to meet the requirements of the Hawai'i State Water Plan and HRS 174C-31(e). Its two main objectives were to 1) assess and plan for an orderly rehabilitation of former plantation irrigation systems, which are considered to be the most important infrastructural requirement to expand Hawai'i's diversified agriculture industry; and 2) ensure that irrigation water supply will be reliable and adequate to meet the current and future water requirements of Hawai'i's diversified agriculture industry.

The 2004 AWUDP identified 21 operational irrigation systems in the state. It focused its evaluation on 13 water systems which, at that time, were considered important and viable to Hawai'i's growing diversified agriculture industry and existing monocrop industry. These systems, as listed below, are owned and managed by HDOA-Agricultural Resource Management Division (ARMD), the Agricultural Development Corporation (ADC), or private owners. For each system, the AWUDP provided an inventory of the system components, a description of the existing condition of the system components, an assessment of needs to improve the system, and proposed capital and maintenance improvements.

- HDOA-ARMD Systems
    - Waimānalo Irrigation System
    - Molokaʻi Irrigation System
    - Upcountry Maui Irrigation System
    - Waimea Irrigation System
    - Lower Hāmākua Ditch Irrigation System

- ADC Systems
    - Kekaha Ditch Irrigation System
    - Kōkeʻe Ditch Irrigation System
    - East Kauaʻi Irrigation System
    - Maui Land and Pineapple/Pioneer Mill Irrigation System
    - Waiāhole Ditch Irrigation System

- Private Systems
    - East Maui Irrigation System
    - Kauaʻi Coffee Irrigation System
    - West Maui Irrigation System

The AWUDP defined the two categories of improvements as follows:

- *Capital improvements*[1] are those that add to and improve the value of the system, and require professional engineering design and construction by licensed contractors; whereas

[1] Capital improvements are funded by the owners. Typically, government owned systems are funded by public funds and privately owned systems are funded by private funds.

- *Maintenance improvements* are those that are necessary to maintain operational efficiency and viability of the system and can be constructed by the system staff with little or no subcontracting work.

In addition to the system inventory, the AWUDP provided source and resource data, as well as forecast water demand. As water demand for diversified agriculture was considered different from monocrops by legal entities, the AWUDP also analyzed water demand for diversified agriculture. Analysis of metered agricultural water demand over an eight-year period provided an estimated diversified agriculture water demand of 3,400 gallons per day per acre (gpd/acre). This agricultural water demand assumed the use of good agriculture practices, such as crop rotation in production fields. Based on the AWUDP's estimated daily water demand for diversified agriculture, the forecast analysis provided agricultural water demand for the 20-year planning period.

1.2 AWUDP UPDATE GOALS AND OBJECTIVES

As in the 2004 AWUDP, this update reaffirms that agricultural water systems (irrigation systems) are the most important infrastructural requirement to expand Hawai'i's diversified agriculture industry; and that irrigation water supply should be reliable and adequate to meet the current and future water requirements of Hawai'i's diversified agriculture industry.

Therefore, the goals of this AWUDP Update are to 1) provide a comprehensive plan to protect and increase the agriculture water resources available to the diversified agriculture industry; and 2) maintain and improve the agricultural water systems in the State of Hawai'i to support an economically viable diversified agricultural industry for the state, achieving the state's goals of agricultural growth, economic diversity, and sustainability.

To achieve these goals, the primary objectives of this AWUDP are to:

- Meet the requirements of HRS 174C-31(e);

- Inventory those water systems which were not inventoried in the 2004 AWUDP;

- Develop a Capital Improvement Program for each of the agricultural water systems;
- Update water demand forecasts; and
- Propose a development plan to meet existing and future needs.

1.3 REPORT ORGANIZATION

This AWUDP Update is organized into nine (9) sections, which are briefly described below.

Chapter 1 contains a brief introduction, a description of the goals and objectives for this AWUDP Update, and the report organization.

Chapter 2 provides the methodology for creating the maps for each irrigation water system studied in this AWUDP.

Chapter 3 contains an inventory of public and private water systems that were not studied in the 2004 AWUDP but have the potential to be important to the diversified agriculture industry. The following systems were inventoried in this AWUDP.

Kaua'i

- Kaloko and Pu'u Ka Ele Ditches
- Stone Dam and Kalihiwai Irrigation Subsystems
- Anahola Ditch
- Upper and Lower Līhu'e Ditches and a portion of Waiahi-'Ili'ili'ula Ditch
- Upper and Lower Ha'ikū Ditches
- Wai'ahi-Ku'ia Aqueduct, por. Waiahi-'Ili'ili'ula Ditch, and Kōloa-Wilcox Ditch
- Olokele Ditch

O‘ahu

- O‘ahu Ditch (Wahiawā, Helemano, Tanaka, and Ito Ditches)
- ‘Ōpae‘ula, and Kamananui Ditches
- Kahuku Irrigation System
- Galbraith Lands Irrigation System

Hawai‘i

- Ka‘ū Agribusiness Irrigation System
- Kohala Ditch
- Kehena Ditch

Chapter 4 provides an update of the system components studied in the 2004 AWUDP. It describes any modifications to the systems since the 2004 AWUDP and provides the current Capital Improvement Program (CIP) for each water system.

Chapter 5 discusses areas with the potential to increase diversified agriculture production if new water systems are developed.

Chapter 6 presents a farm survey for agriculture water demand and the analysis to determine agricultural water demand rate.

Chapter 7 presents the major limitations, concerns, and policies which may affect crop water demand and the diversified agricultural industry, such as system losses and water rights and management.

Chapter 8 provides a forecast for the agricultural water demand in the short and long term.

Chapter 9 presents a development plan which includes the short-term improvement program and provides suggestions for long-term management of the agricultural water systems.

CHAPTER 2
INVENTORY METHODOLOGY

Farming looks mighty easy when your plow is a pencil, and you're a thousand miles from the corn field.

Dwight D. Eisenhower

The AWUDP Update includes an inventory of 13 private and public irrigation systems in the counties of Kaua'i, O'ahu, and Hawai'i. The system inventory includes a condition assessment of the irrigation system components, if possible; the potential service area associated with the irrigation system; the agricultural use (land use) within the service area; land capability (soil capability) for agriculture; the identification of IAL and water sources; and proposed CIP for the next five (5) years.

The information gathered for the system inventory is graphically depicted in a map series for each agricultural water system and used to develop a CIP. The following subsections provide a description of the methodology used to collect the information and develop the CIP. This chapter provides a general discussion of the information and maps. The detailed information for each agricultural water system is presented in Chapters 3 and 4, and the map series are presented in Appendix A.

Section 2.1 describes the general background information and methodology used to collect the system alignments and component information, as well as the development of the CIP. Section 2.2 describes the methodology used to identify the various land uses (crop categories) for each water system, and section 2.3 discusses the Agricultural Land of Importance to the *State of Hawai'i* (ALISH) map. Section 2.4 discusses the land capability maps, presenting the land capability for non-irrigated and irrigated conditions. Section 2.5 discusses the IAL map.

2.1 SYSTEM ALIGNMENTS, COMPONENTS, AND CIP

2.1.1 METHODOLOGY AND ANALYSIS

The system alignment verification and system component inventory utilized a walkthrough, as well as analysis of satellite and aerial imagery. The initial step was to acquire access to the irrigation system. If granted,[2] a condition assessment of irrigation system components was performed by walking the length of the system. The walkthrough provided a visual inspection of system components, including the water source, and a handheld global positioning system (GPS) was used to record the location of each component. The GPS location data had an accuracy of one (1) meter and was inputted into a geographical information system (GIS).

The condition of the system components did not utilize any destructive or nondestructive testing. The condition of the system used three (3) broad categories for the condition rating, as follows:

- poor – the component had large areas of deterioration, structural damage, or both;

---

[2] HDOA does not have statutory authority to require that owners/managers grant access to their irrigation systems and considered enlisting the CWRM's authority to gain access. However, upon further consideration, the HDOA determined the following:

1. Private owners are committed to providing agricultural water to farmers in their service area. In this effort, they are sharing HDOA's mission of supporting agricultural efforts in the state. The use of CWRM's authority to gain access may create the impression that the AWUDP Update is not solely a product of HDOA.
2. Private owners are ultimately responsible for any maintenance and rehabilitation efforts on their system(s). The AWUDP assists in determining rehabilitation efforts to maintain and improve systems, as well as to prevent system failure. Copies of the AWUDP Update will be provided to private system owners/operators as a tool to review their system and identify any necessary improvements.
3. Other sources could still be used to provide information about irrigation systems, their agricultural capacity, and crop categories.

As such, HDOA elected against using CWRM's authority to gain access to irrigation systems. HDOA believes that the information included in the AWUDP Update is beneficial. It should be noted that HDOA will also pursue access and additional cooperation for future AWUDP updates.

- fair – limited deterioration, no structural damage, and/or moderate overgrowth; and
- good – minor deterioration, maintained with little overgrowth.

If access was not granted, the condition of the system was performed by using data from publicly available reports on the condition of the irrigation system, and discussions with the system owner or irrigation manager, if possible. In cases where a visual inspection of the irrigation system was impossible, a condition assessment of system components could not be performed, water source information and system components were not verified, and the five (5)-year CIP is unknown. However, it should be noted that if a system is currently in use for agricultural purposes, then it should have potential for improvements and/or rehabilitation.

Information for each system's dams, reservoirs, and water sources were obtained from the DLNR, Engineering Division; and CWRM.[3] The hydrologic units (aquifers) were identified using publicly available maps. The potential service area for each system was determined through interviews with system owners, maps, imagery analysis, HDOA data, proximity to the distribution mains, and topography. A compilation of reported water flow data is presented in Appendix D.

2.1.2 ALIGNMENTS AND SYSTEM COMPONENTS MAP

The first map in the map series (Appendix A) is the *Alignment and System Component* map. This map presents the system alignment; the location and identification of the active, inactive, and unverified system components, such as ditches, tunnels, flumes, intakes, siphons, penstocks, reservoirs, and dams; the potential service area; and neighboring systems. The neighboring systems are shown, as the systems may be physically linked and may share water resources, currently or in the past.

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[3] CWRM has limited authority on water sources, and these systems have reported to CWRM voluntarily.

2.1.3 CAPITAL IMPROVEMENT PROGRAM

The AWUDP Update is intended to address the repair, maintenance, and rehabilitation of the system through the development of a CIP for each agricultural water system. The CIP funding source is dependent upon the system owner and whether it is a public or private system.

Based on the interviews with system owners and the condition inventory (described in Section 2.1.1), a CIP was developed for each system. For most systems, a long-term plan was not available; therefore, the proposed CIP is based on short-term projects. As part of the CIP program discussion, long-term management options are discussed in other chapters of this document.

2.2 LAND USE

Since the plantation era, and even since the 2004 AWUDP, the definition of diversified agriculture[4] has changed. Previously, diversified agriculture was typically defined as agricultural crops other than sugarcane and pineapple. However, as there are no large sugarcane growers in the state today and only one large pineapple farm, that definition of diversified agriculture is outdated. Therefore, in this document, "diversified agriculture" encompasses all agricultural crops in the State of Hawai'i.

2.2.1 DEFINITIONS OF FARMING AND AGRICULTURAL LAND

To provide a uniform evaluation of the various water systems in this AWUDP, two terms are defined. The following definitions from the relevant HRS are presented for farming and agricultural land. HRS Chapter 165-2 defines a farming operation as follows:

> *"Farming operation" means a commercial agricultural, silvicultural, or aquacultural facility or pursuit conducted, in whole or in part, including the care and production of livestock and livestock products, poultry and poultry products, apiary products, and plant and animal production for nonfood uses; the planting, cultivating, harvesting, and processing of crops; and the farming*

[4] Philipp, Perry F. "*Diversified Agriculture of Hawai'i*," University of Hawai'i Press, 1953.

or ranching of any plant or animal species in a controlled salt, brackish, or freshwater environment.

HRS Chapter 167 defines agricultural land and farming as follows:

- *"Agricultural land" means that portion of the land of a land occupier lying within an existing or proposed irrigation project and of such location and character as may be profitably employed in the growing of irrigated crops; and "pasture land" means that portion of the land of a land occupier lying within an existing or proposed irrigation project and of such location and character as may be suitable with the use of water for irrigated pasture and may be profitably employed in the production of livestock or poultry.*

- *"Farming" means agricultural pursuits, including the care and production of livestock and poultry, engaged in by a land occupier owning or leasing land, within any existing or proposed irrigation project.*

2.2.2 METHODOLOGY AND ANALYSIS

For each irrigation system, a land use analysis was performed using publicly available aerial imagery and satellite imagery, and new aerial imagery for specific areas with diversified crop mix. The publicly available satellite imagery resolution of two (2) meters was acquired in 2011. The new aerial imagery was obtained in 2014 for this project at a resolution of four centimeters (4 cm) to assist in crop determination in specific production areas, using a piloted aircraft with multiple GPS sensors to obtain an accurate location of the imagery.

Satellite and aerial imagery were processed with vegetation-recognition software, which was calibrated to crops in Hawai`i. To the extent possible, the land use information was verified with an aircraft overflight, discussions with system owners, or by visual inspection from the ground. Exhibits 1 to 6 are examples of the aerial and satellite images. Exhibits 7 and 8 are examples of the processed images. A detailed methodology of the imagery analysis is presented in Appendix E.

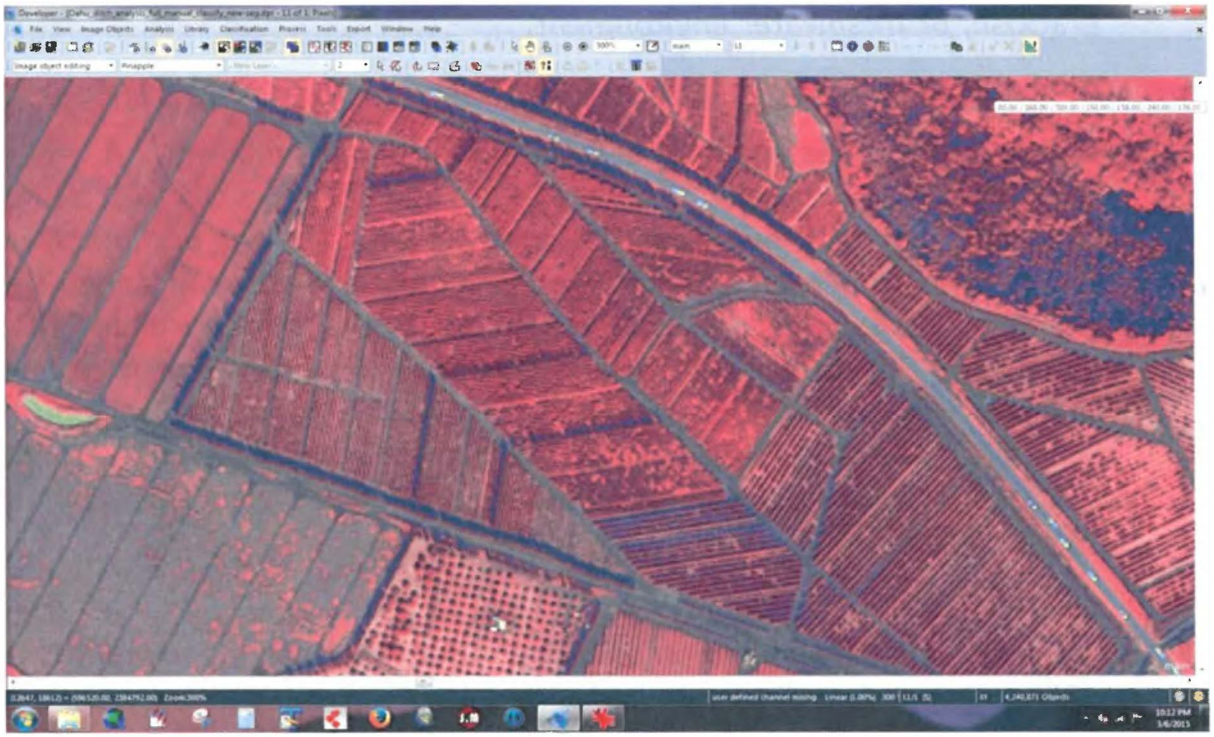

Exhibit 1. World View II satellite (2-meter resolution) - Coffee

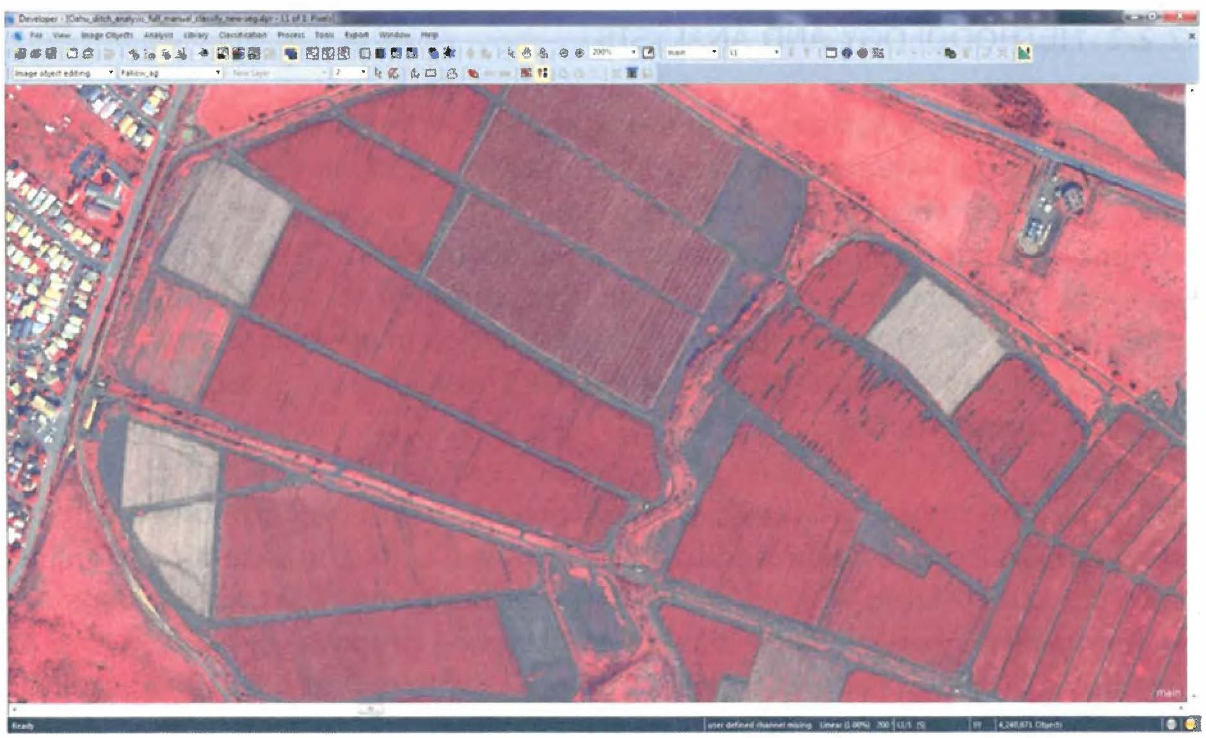

Exhibit 2. World View II satellite (2-meter resolution) - Corn

Exhibit 3. Aerial Imagery (4-centimeter resolution) - Fruit and nut trees

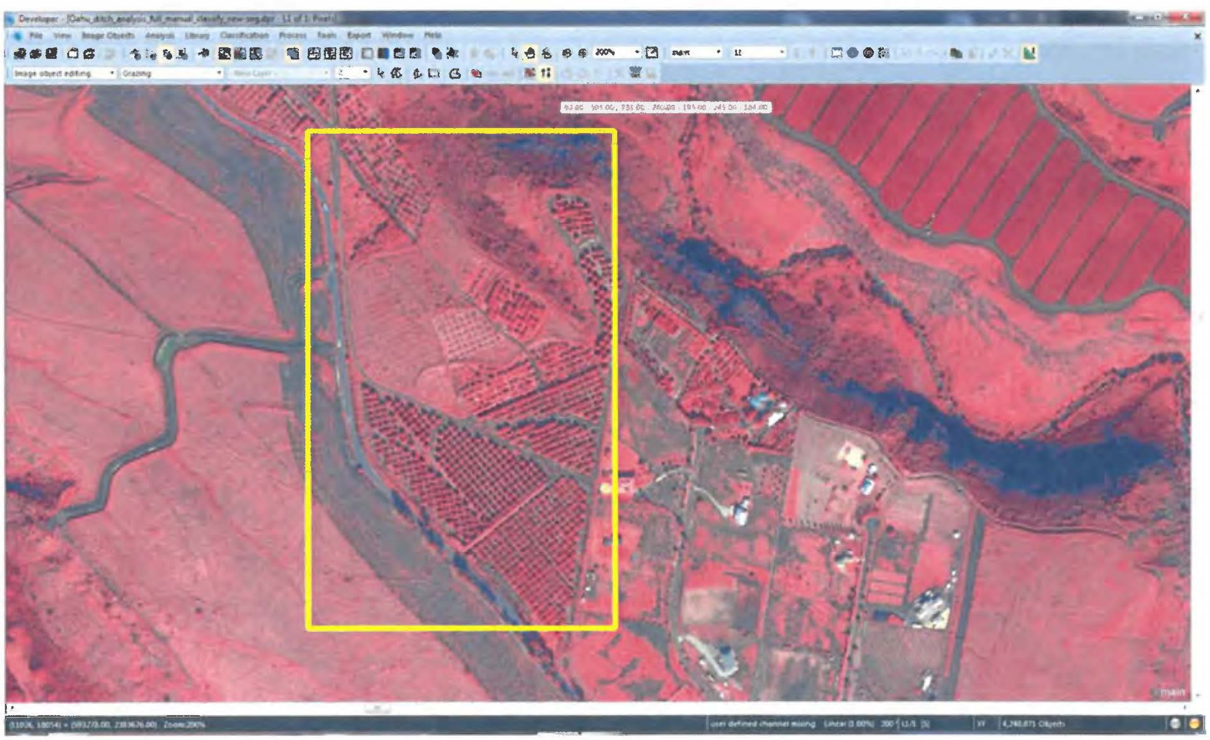

Exhibit 4. World View II satellite (2-meter resolution) - Fruit and nut trees

Exhibit 5. Aerial Imagery (4-centimeter resolution) - Miscellaneous produce

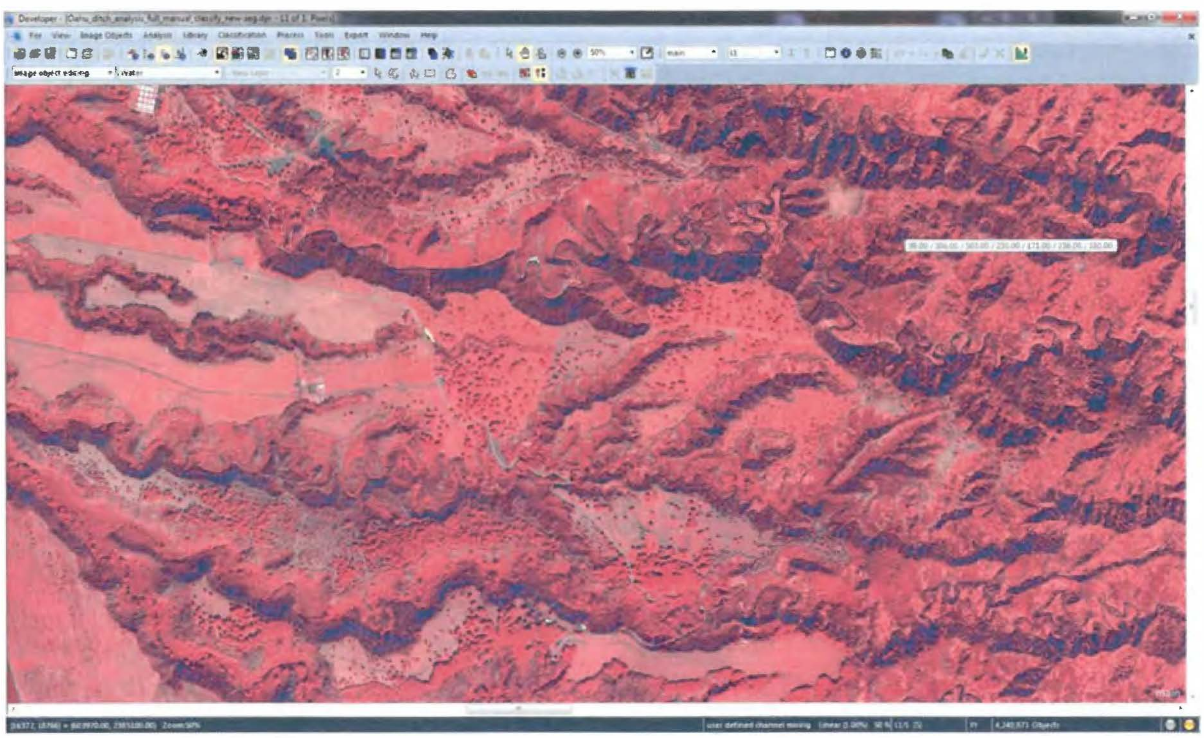

Exhibit 6. World View II satellite (2-meter resolution) - Grazing

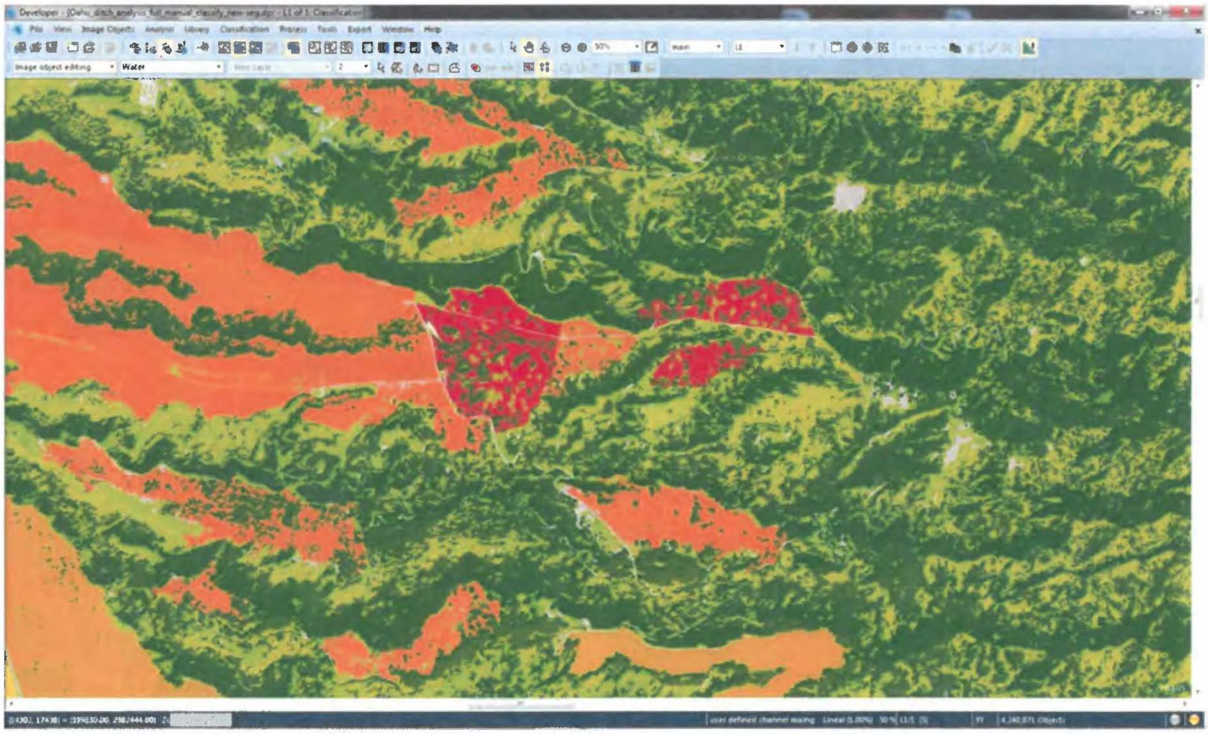

Exhibit 7. eCognition™ Processed Data - Active grazing lands in orange; inactive grazing in red

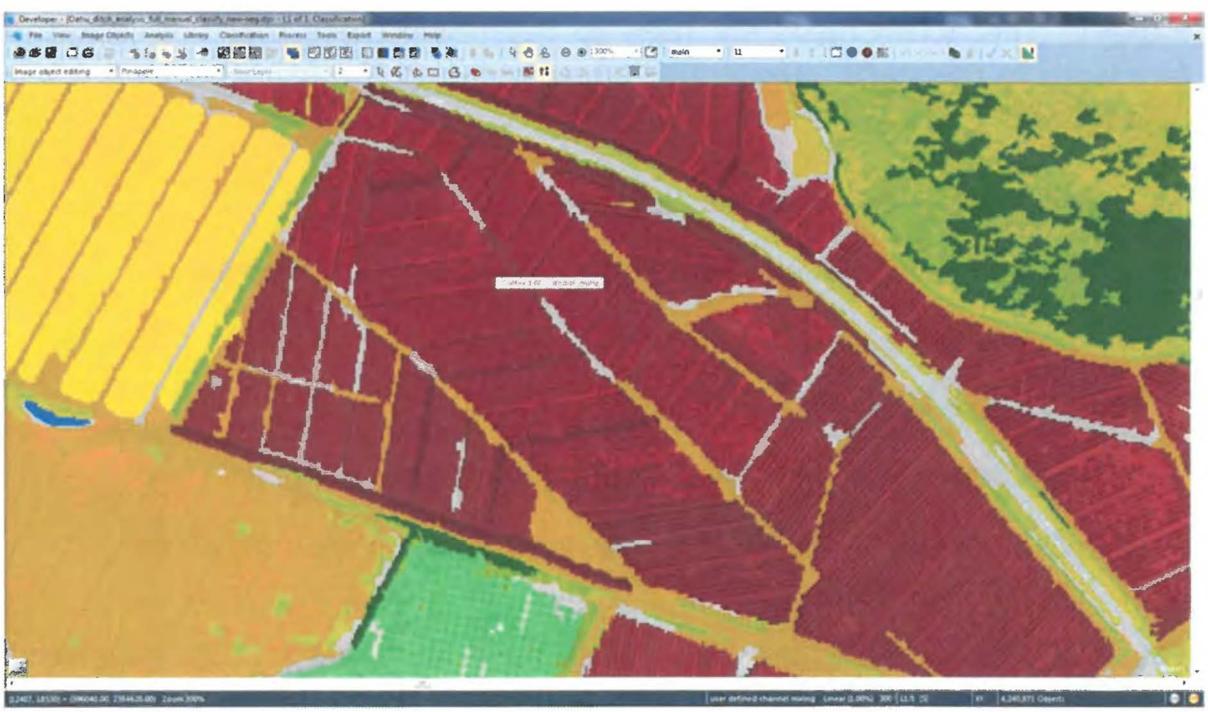

Exhibit 8. eCognition™ Processed Data – Coffee in red

2.2.3 LAND USE MAP

The second map in the series (Appendix A) is the land use map that shows agricultural crop categories occurring within the system's service area. The map depicts land use as one of three (3) broad categories of land use (crops): 1) Grazing, 2) Field Crops, and 3) Other Crops. The Grazing category is the area used for animal grazing. The Field Crops category includes crops such as, but not limited to, agroforestry, sugarcane, pineapple, coffee, and grain corn. The Other Crops category includes crops such as, but not limited to, vegetables, papaya, landscaping, fruit trees, and nut trees.

2.3 AGRICULTURAL LANDS OF IMPORTANCE TO THE STATE OF HAWAIʻI

2.3.1 METHODOLOGY AND ANALYSIS

The *Agricultural Lands of Importance to the State of Hawaiʻi* (ALISH) maps are based on the publicly available GIS data set from the State of Hawaiʻi. The ALISH map series was developed in 1977 by HDOA, with assistance from the Soil Conservation Service, U.S. Department of Agriculture, and University of Hawaiʻi. The ALISH maps are used to determine lands that are important farmlands in the state. The ALISH study excluded the following land use or land types:

- developed urban lands over 10 acres;
- natural or artificial enclosed bodies of water over 10 acres;
- forest reserves;
- public use lands such as parks and historical sites;
- lands with slopes in excess of 35 percent; and
- military installations, except undeveloped areas over 10 acres.

The analysis grouped the remaining lands into three (3) importance categories: Prime, Unique, and Other Important. Each category is described below.

- **Prime Agricultural Land** is land best suited to produce food, feed, forage, and fiber crops. The land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods.

- **Unique Agricultural Land** is land other than Prime Agricultural Land that is used to produce specific high-value food crops. These lands have the special combination of soil quality, growing season, temperature, humidity, sunlight, drainage, elevation, aspect,[5] moisture supply, or other conditions, such as nearness to market, that favor the production of a specific crop of high quality and/or high yield when the land is treated and managed according to modern farming methods. In Hawai`i, some examples of such crops are coffee, taro, rice, watercress, and non-irrigated pineapple.

- **Other Important Agricultural Land** is land other than Prime or Unique Agricultural Land that is of statewide or local importance to produce food, feed, fiber, and forage crops. The lands in this classification are important to agriculture in Hawai`i, but they exhibit properties, such as seasonal wetness, erodibility, limited rooting zone, slope, flooding, or drought potential that exclude them from the Prime or Unique Agricultural Land classifications.

  Two examples of Other Important Agricultural Land include lands that do not have an adequate moisture supply to qualify as Prime Agricultural Land, and lands that have similar characteristics and properties as Unique Agricultural Lands, except that these lands are not currently in use to produce a "unique" crop. These lands can be farmed to produce fair to good crop yields when managed properly, such as by applying greater inputs of fertilizer and other soil amendments, drainage improvement, erosion control practices, and/or flood protection.

[5] Aspect - direction that the slope faces for agriculture, as it relates to sun exposure.

2.3.2 AGRICULTURAL LANDS OF IMPORTANCE TO THE STATE OF HAWAI'I MAP

The ALISH map is the third map of the series, and presents the prime, unique, and other agricultural land within the service area. There are certain areas that do not have an ALISH land category and are depicted on the map as "service area without ALISH designation."

2.4 LAND CAPABILITY CLASSIFICATION

The Land Capability Classification (LCC) was developed by the USDA Soil Conservation Service in 1972, based on Agriculture Handbook No. 210, which was issued in 1961.[6] Each capability classification is a grouping of soils with similar agricultural potential and limitations. Hawai'i soils were classified using soil surveys by the U.S. Department of Agriculture and University of Hawai'i. The agricultural productivity element of the analysis was based on soil and climatic conditions, with a preference for field crops (sugarcane, pineapple, pasture, and woodland) and mechanization.

2.4.1 METHODOLOGY AND ANALYSIS

Similar to the ALISH data, the LCC data set is publicly available from the National Resources Conservation Service (NRCS). The LCC has eight (8) broad groups, numbered I to VIII.

- Class I soils have few limitations that restrict their use, are suited for a wide range of plants, and may be used safely for cultivated crops, pasture, range, woodland, and wildlife.
- Class II soils requires careful soil management, including conservation practices, to prevent deterioration or to improve air and water relations when the soils are cultivated. The soils may be used for cultivated crops, pasture, range, woodlands, or wildlife food and cover.
- Class III soils have severe limitations that reduce the choice of plants or require special conservation practices, or both. These soils may be used

---

[6] Klingebiel, A. A. and P. H. Montgomery, "*Land-Capability Classification*," Soil Conservation Service, Agriculture Handbook N. 210, September 1961.

for cultivated crops, pasture, woodland, range, or wildlife food and cover.

- Class IV soils have very severe limitations that restrict the choice of plants, require very careful management, or both. These soils may be used for crops, pasture, woodland, range, or wildlife food and cover.
- Class V soils have little or no erosion hazard but have other limitations to remove that limit their use largely to pasture, range, woodland, or wildlife food and cover.
- Class VI soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.
- Class VII soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife.
- Class VIII soils and landforms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or aesthetic purposes.

The LCC are based on a non-irrigated and in-situ state. The USDA's classification system indicates that certain soils have a limitation due to water availability (arid or semi-arid areas). Therefore, if this limitation is mitigated by irrigation, there is a potential for the soil to be reclassified to a higher classification. An analysis was performed based on an irrigated state for the soils.

2.4.2 LAND CAPACITY CLASSIFICATION MAPS

The LCC maps are the fourth (non-irrigated) and fifth (irrigated) maps in the series (Appendix A). The LCC non-irrigated map is the LCC based on the soil ratings from USDA. To show the importance of irrigation relative to soil productivity, the LCC irrigated map shows the potential LCC when irrigation is applied. There are some areas in which the LCC does not improve the classification and are shown on the LCC irrigated map with the cross-hatching. On both maps, USDA did not classify certain areas; these are shown as "service area without soil designation."

2.5 IMPORTANT AGRICULTURAL LANDS

2.5.1 IMPORTANT AGRICULTURAL LANDS DESCRIPTION

As required by state statute, the AWUDP must identify the water sources and existing and future water needs for Important Agricultural Lands (IAL). The IAL statutes are found in HRS Chapter 205-Part III, and the purpose of the IAL follows.

> *It is declared that the people of Hawai'i have a substantial interest in the health and sustainability of agriculture as an industry in the State. There is a compelling state interest in conserving the State's agricultural land resource base and assuring the long-term availability of agricultural lands for agricultural use to achieve the purposes of:*
>
> *(1) Conserving and protecting agricultural lands;*
> *(2) Promoting diversified agriculture;*
> *(3) Increasing agricultural self-sufficiency; and*
> *(4) Assuring the availability of agriculturally suitable lands, pursuant to article XI, section 3, of the Hawai'i state constitution.*

2.5.2 IDENTIFICATION OF IMPORTANT AGRICULTURAL LANDS

The list and areas granted IAL[7] status were obtained from the Land Use Commission website (http://luc.hawaii.gov/maps/important-agricultural-lands-ial-maps/). As of 2018, approximately 134,510 acres of agricultural land have been designated as IAL on four islands and are shown on Map 1. Tables 1 to 3 list the IAL in each county and identifies their locations and water source. The associated "Agricultural Water System" for each IAL area, as defined for this study, is shown in the respective tables. The associated water

[7] Declaratory orders were obtained from: http://luc.hawaii.gov/completed-dockets/declaratory-orders-decisions-and-order/declaratory-orders-oahu-county/declaratory-orders-important-agricultural-lands-designations/

use and current water demand for each IAL is identified in its respective IAL Petition and Decision and Order. These current water demands are presented in the corresponding Agricultural Water System discussions detailed in Chapters 3 and 4 of this report.

Table 1
Important Agricultural Lands in Kaua'i County

Map Index	Island Location	Landowner	Area (Acres)	Predominant Agriculture Uses	Water Source**	Agricultural Water System
1	Kaua'i, Kōloa	Kaua'i Coffee (Alexander & Baldwin)	3,773	Coffee, seed corn	Wells, surface water Pump 3 and Alexander system	Kaua'i Coffee Irrigation System
2	Kaua'i, Kōloa	Māhā'ulepū Farm, LLC (Grove Farm)	1,533	Taro, seed corn, forage crops, cattle ranching	Waitā Reservoir	Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch Irrigation System
3	Kaua'i, Hā'upu/ Līhu'e	Grove Farm Company, Inc.	11,206	Biomass production for renewable energy, cattle ranching	Rainfall, various on-site and off-site water sources	Līhu'e and Ha'ikū Ditch Systems
4	Kaua'i, Lumaha'i/ Waipā	Kamehameha Schools	190	Taro, diversified vegetable and fruit crops, plant nursery, cattle ranching	Lumaha'i: Lumaha'i River Waipā: Waipā Stream	Not Applicable
5	Kaua'i, Makaweli	Robinson Family Partners	20,888	Ranching and crop production	Kō'ula Ditch System and Olokele Ditch System	Kō'ula Ditch System and Olokele Ditch System

Note: ** various 'Decisions and Orders,' State of Hawai'i, Land Use Commission, circa 2018.

Table 2
Important Agricultural Lands on O'ahu

Map Index	Island Location	Landowner	Area (Acres)	Predominant Agriculture Uses	Water Source**	Agricultural Water System
6	O'ahu, Central and North Shore	Castle and Cooke Homes Hawai'i, Inc.	679.4 (3 parcels)	Diversified vegetable and fruit crops, flowers, foliage	Dole Ditch System and rainfall (O'ahu Ditch)	O'ahu Ditch
7	O'ahu, Kawailoa/ Punalu'u	Kamehameha Schools	9,591.8	Grazing, diversified agriculture	Kawailoa: Waimea & Anahulu Rivers; Ka'alaea, Kawailoa, & Laniākea Streams Punalu'u: Punalu'u Stream	Not Applicable
8	O'ahu, Kunia	Monsanto Company	1,550	Agriculture	Waipahu-Waiawa, Kahana and Ko'olaupoko aquifers Waiāhole Ditch	Waiāhole Ditch System
9	O'ahu, Kunia	Hartung Brothers Hawai'i, LLC	462.967	Crop production, and soil conservation	Waiawa, Waiāhole, Waikāne, Uwao, Kahana Tunnels Waiāhole Ditch	Waiāhole Ditch System
10	O'ahu, Kualoa	Kualoa Ranch, Inc.	761.55	Ranching, diversified agriculture and aquaculture	City and County of Honolulu Board of Water Supply, Hakipu'u Stream in Hakipu'u Valley, two drilled wells in Ka'a'awa Valley	Not Applicable

Note: ** Various 'Decisions and Orders,' State of Hawai'i, Land Use Commission, circa 2018.

Table 3
Important Agricultural Lands in Maui and Hawaiʻi Counties

Map Index	Island Location	Landowner	Area (Acres)	Predominant Agriculture Uses	Water Source**	Agricultural Water System
11	Maui, Central	Alexander & Baldwin	27,102	Sugarcane As of 2016, diversified agriculture	Various sources: East Maui Irrigation System & West Maui Ditch System	East Maui Irrigation System & West Maui Ditch System
12	Hawaiʻi, South Kohala	Parker Ranch, Inc.	56,771.8	Cattle ranching	Kohākōhau, Alakahi and Waikoloa Streams	Not Applicable

Note: ** various 'Decisions and Orders,' State of Hawaiʻi, Land Use Commission, circa 2018.

Future water demand for IALs are not forecast to change from the current water demand values, as they are expected to reflect the same planted acreage, farming method, and crop type. Modifications to any of these factors may result in different water demand values for the affected IALs. Climate change is expected to potentially reduce rainfall and may affect other growing factors, resulting in an increase to future agricultural water demand.

2.5.3 IMPORTANT AGRICULTURAL LANDS MAP

The IAL map is the sixth of the map series (Appendix A) for those agricultural water systems that have IAL. The IAL maps show the IAL area as a cross-hatched area that may be larger than the potential service area and/or associated with multiple water systems. Those IAL areas that are not associated with agricultural water systems, such as Punaluʻu, Parker Ranch, Inc., and Kualoa Ranch, Inc., are not shown on any maps.

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CHAPTER 3
2018 AGRICULTURAL WATER SYSTEMS

Agriculture is the most healthful, most useful, and most noble employment of man.
George Washington

The systems studied in 2018 are considered important to the agricultural economies on each island and to the designated IAL. These systems have various owners, including ARMD, ADC, and private entities. In total, 13 systems were inventoried in 2018 with the intention of completing the master inventory of the agricultural water systems, initiated by the 2004 AWUDP, as required in HRS Chapter 174C-31(e).

This chapter will provide descriptions of and pertinent information for each irrigation system. The analysis of each system will include a determination of the rehabilitation potential and proposed projects for the CIP. The sections will describe the agricultural water systems by island: 3.1 - Kaua'i; 3.2 - O'ahu; and 3.3 - Hawai'i.

3.1 KAUA'I COUNTY IRRIGATION SYSTEMS

The following systems were studied in Kaua'i County, and their locations are shown in Exhibit 9.

- Kīlauea Sugar Company (Kaloko to Kalihiwai):
    - Kaloko Irrigation;
    - Pu'u Ka Ele and Morita Reservoir;
    - Stone Dam; and
    - Kalihiwai.
- Anahola Ditches.
- Upper and Lower Līhu'e Ditches and a portion of the Waiahi-'Ili'ili'ula Ditch.
- Upper and Lower Ha'ikū Ditches.
- Wai'ahi-Ku'ia Aqueduct, portion of the Waiahi-'Ili'ili'ula Ditch, and Kōloa-Wilcox Ditch.
- Olokele Ditch.

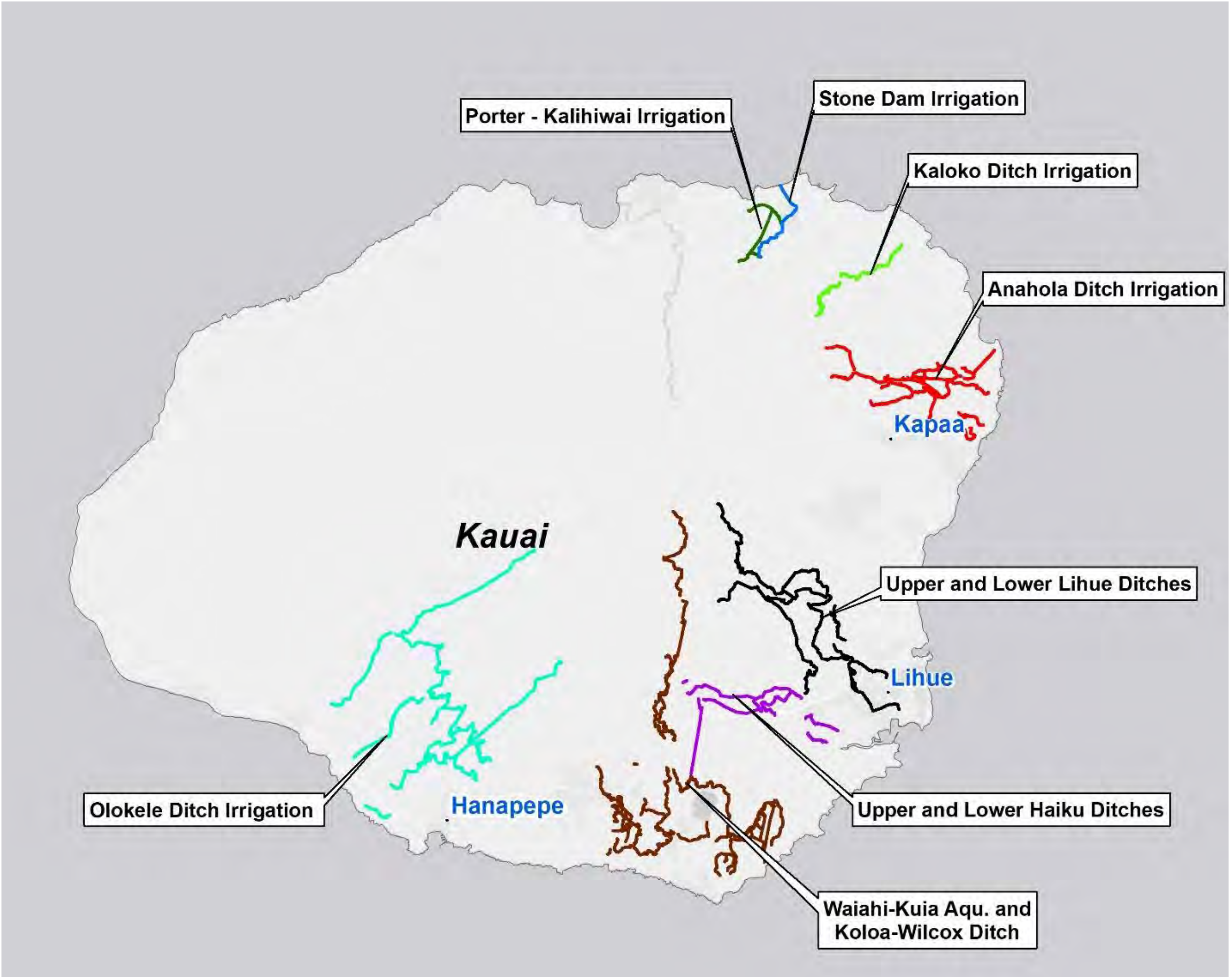

Exhibit 9. Water Systems Inventoried on Kauaʽi

3.1.1 KĪLAUEA SUGAR COMPANY (KALOKO TO KALIHIWAI)

Beginning in 1880, Kīlauea Sugar Company, Ltd. owned and developed irrigation systems from Kaloko to Kalihiwai. According to Wilcox[8], this irrigation system was comprised of a network of small ditch systems, with a total storage capacity of over 730 million gallons (MG). This system was able to irrigate over 3,000 acres of sugar cane, stretching over six (6) miles.

Currently, there are two (2) active rainfall stations in the area: one at Koloko Reservoir and the other in Kīlauea. The Koloko Reservoir station is at an

[8] Wilcox, Carol, *Sugar Water, Hawaiʽi's Plantation Ditches,* Honolulu, University of Hawaiʽi Press, 1996.

elevation of 735 feet, showing a mean annual rainfall of 83.69 inches. The Kīlauea Station is at an elevation of 315 feet, showing a mean annual rainfall of 63.64 inches.

Upon the closure of Kīlauea Sugar Company, Ltd. in 1971, the company's land assets were subdivided and sold to various entities. The new landowners inherited the irrigation system components associated with their specific properties. Therefore, the small ditch systems no longer function as a network, and the sugar company's irrigation system has been subdivided into four major standalone subsystems: 1) Kaloko Ditch, 2) Pu'u Ka Ele-Morita Reservoir; 3) Stone Dam; and 4) Kalihiwai.

3.1.1.1 Kaloko Irrigation Subsystem

Ownership and service area information for the Kaloko Irrigation Subsystem is presented in Table 4. General system information is presented in Table 5. On March 14, 2006, the Kaloko Dam failed, resulting in a breach that impacted the residential area below the dam. The incident led to legal action against various parties, and the capacity of the Kaloko Reservoir was decreased to 48 MG. Table 6 presents land use within the service area. The system maps are shown on Maps 2 to 6:

- Map 2 - Alignments and System Components;
- Map 3 - 2014-2015 Land Use;
- Map 4 - ALISH 1977;
- Map 5 - Land Capability Non-Irrigated Conditions; and
- Map 6 - Land Capability Irrigated Conditions.

Assessment of Needs. As a condition assessment was not completed, the CIP was not developed. However, in June 2009, a study was completed by Sustainable Resources Group International, Inc. for the County of Kaua'i, Office of Economic Development, titled *Kīlauea Irrigation Water Engineering Design and Monitoring Study.* The study determined that the system is currently in use and should be rehabilitated and maintained for its users. The study states:

> *The existing systems have deficiencies with respect to the ditch network and mechanical components, as well as regulatory, legal,*

and institutional issues that, unless resolved, place the continued use of the systems in jeopardy.

However[,] it is our conclusion that these deficiencies can be overcome, and with some improvements to both the infrastructure and operations, the systems can continue to function into the foreseeable future ...

... the most hydrologic and economically feasible alternative is to continue using the existing KICO and Ka Loko systems, including Ka Loko Ditch, Dam and Reservoir.

Table 4
Kaloko Irrigation Subsystem
System Ownership and Service Area

Description	Information
Owners	Mary N. Lucas Trust (803 acres), Pflueger Partners (110 acres), Circensa (71 acres)
Source	Puʻu Ka Ele Stream Kaluaa Stream (Moloaʻa Forest Reserve)
Estimated Current Water Use (annual average)	0.098 MGD
Estimated Service Area	1,862 acres
Farms Served	Kīlauea Farm Subdivision – 28 Farm lots Mary Lucas Trust – grazing
Important Agricultural Lands	None

Table 5
Kaloko Irrigation Subsystem
General System Information

Description	Information	
System Length (feet) / status	15,450 (Unverified)	
Intake	Kaloko Ditch	Moloa'a Ditch
Source (type)	Pu'u Ka Ele Stream (Surface Water)	Kaluaa Stream (Surface Water)
Hydrologic Unit	Kīlauea	Kīlauea
Intake Status	Active	Active
Reservoirs	Kaloko	Waiakalua
Capacity (acre-feet / MG)	1,400/456.2	184/60
Status	Active, capacity is reduced 147 acre-feet (408.3 MG)	Active
Visual inspection undertaken	No	
Irrigation system condition	Condition assessment was not performed	
Rehabilitation Potential	Fair, requires resolution of regulatory, legal, and institutional issues	
Rehabilitation Cost / CIP	To be determined by system owner	

Reference: Sustainable Resources Group International, Inc., "*Kīlauea Irrigation Water Engineering Design and Monitoring Study*," County of Kaua'i, Office of Economic Development, Final Report, June 2009.

Table 6
Kaloko Irrigation Subsystem
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	0
Other Crops	60.7
Grazing	945.4

3.1.1.2 Puʻu Ka Ele and Morita Reservoir Irrigation Subsystem

Ownership and service area information for the Puʻu Ka Ele and Morita Reservoir Irrigation Subsystem is presented in Table 7. General information about the system is presented in Table 8. The Jurassic Kāhili Ranch was created by purchasing 2,300 acres from the Mary N. Lucas family in 2003, and it is currently used for ranching, maintaining over 200 head of cattle. Discussions with Jurassic Kāhili Ranch personnel[9] indicate that the entire system is inactive (not in use or demolished), including both the Puʻu Ka Ele and Morita Reservoir.

Assessment of Needs. As the system is not in use and, in fact, some portions of it have been demolished, the Puʻu Ka Ele and Morita Reservoir Irrigation Subsystem should not be rehabilitated. Therefore, the locations and identification of the system components were not mapped and maybe non-existent.

Table 7
Puʻu Ka Ele and Morita Reservoir Irrigation Subsystem
System Ownership and Service Area

Description	Information
Owners	Jurassic Kāhili Ranch
Source	Inactive and Unverified (1)
Estimated Current Water Use (annual average)	None
Estimated Service Area	0 acres
Farms Served	Jurassic Kāhili Ranch
Important Agricultural Lands	None

Note: 1. Telephone communication

[9] Personal communication.

Table 8
Pu'u Ka Ele and Morita Reservoir Irrigation Subsystem
General System Information

Description	Information
System Length (feet) / status	Unverified as portions have been demolished (demolished)
Intake	Unverified
Source	Unverified
Hydrologic Unit	Unverified
Intake Status	Unverified
Reservoirs	None
Visual inspection undertaken	No
Irrigation system condition	Inactive, portions of the system have been destroyed
Rehabilitation Potential	Not recommended
Rehabilitation Cost / CIP	To be determined by owner

3.1.1.3 Stone Dam Irrigation Subsystem

Ownership and service area information for the Stone Dam Irrigation Subsystem is presented in Table 9. General system information is presented in Table 10. The Stone Dam was constructed by John Ross and E.P. Adams in 1880. Land use areas within the service area are presented in Table 11. The system maps are shown on Maps 7 to 11:

- Map 7 - Alignments and System Components;
- Map 8 - 2014-2015 Land Use;
- Map 9 - ALISH 1977;
- Map 10 - Land Capability Non-Irrigated Conditions; and
- Map 11 - Land Capability Irrigated Conditions.

Table 9
Stone Dam Irrigation Subsystem
System Ownership and Service Area

Description	Information
Owner(s)	Bridgewater Irrigation (System Manager)
Source	Pohakuhono and Hālaulani streams
Estimated Current Water Use (annual average)	Unverified
Estimated Service Area	130 acres
Farms Served	Unverified Provides backup water to the Kalihiwai agricultural water subsystem
Important Agricultural Lands	None

Table 10
Stone Dam Irrigation Subsystem
General System Information

Description	Information
System Length (feet) / status	7,286 (Active)
Intake Source Hydrologic Unit Intake Status	Stone Dam Pohakuhono and Hālaulani streams Kīlauea Active
Reservoir	Stone Dam (capacity unknown)
Visual inspection undertaken	Publicly accessible portions only
Irrigation system condition	Active
Rehabilitation Potential	Good
Rehabilitation Cost / CIP	To be determined by system owner

Table 11
Stone Dam Irrigation Subsystem
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	0
Other Crops	50.6
Grazing	7.5

Assessment of Needs. The publicly accessible portions of the irrigation system were visually observed, but an interview and formal permission for access was not obtained. As a condition assessment was not completed, the CIP was not developed. The system is currently being used, and the publicly visible portions are in good condition. The Stone Dam Irrigation Subsystem provides backup irrigation water to the Kalihiwai Irrigation Subsystem through a pipeline connection.

3.1.1.4 Kalihiwai Irrigation Subsystem

Ownership and service area information for the Kalihiwai Irrigation Subsystem is presented in Table 12. General system information is presented in Table 13. Kalihiwai Reservoir was constructed in 1920 to provide a reliable water source for the sugar industry. Table 14 presents the land use area within the service area. The system maps are shown on Maps 12 to 16:

- Map 12 - Alignments and System Components;
- Map 13 - 2014-2015 Land Use;
- Map 14 - ALISH 1977;
- Map 15 - Land Capability Non-Irrigated Conditions; and
- Map 16 - Land Capability Irrigated Conditions.

Assessment of Needs. The Kalihiwai Irrigation Subsystem was surveyed in 2014 and found to be in relatively good condition. Porter Irrigation provided permission and information for the Kalihiwai Irrigation Subsystem and coordinated the inventory survey with various private landowners in the area.

The upper (mauka) section above the reservoir is a 4,000-foot-long ditch and tunnel system that runs through private lands. There are easements or negotiated access points to maintain the ditch on these private lands. The lower portion of the system, downstream of the Kalihiwai Reservoir, consists of a six (6)-inch pipeline and valves that have been recently installed for irrigation and fire protection.

The significant issue is deterioration of the ditches and tunnels due to age and excessive overgrowth, including invasive species. Exhibits 10 and 11 show examples of the excessive overgrowth in a portion of the ditch. The ditch walls and tunnels are collapsing, creating partial or full blockages in the portions of the system, thus reducing water flow to the agricultural users.

Table 12
Kalihiwai Irrigation Subsystem
System Ownership and Service Area

Description	Information
Owners	Various owners Kalihiwai Reservoir – Kalihiwai Ridge Community Associations Porter Irrigation System (System Manager)
Source	Pohakuhonu Stream
Estimated Current Water Use (annual average)	100,000 gpd During plantation era – estimated at 10 MGD
Estimated Service Area	794 acres
Farms Area Served Potential Farming	200 acres – mahogany trees 150 acres – community farms Potential increase if water available
Important Agricultural Lands	None

Table 13
Kalihiwai Irrigation Subsystem
General System Information

Description	Information	
System Length (feet) / status	17,380 (Active)	
Intake	Kalihiwai Intake 1	Kalihiwai Mauka Intake
Source	Pohakuhonu Stream	Pohakuhonu Stream
Hydrologic Unit	Kīlauea	Kīlauea
Intake Status	Active	Inactive
Reservoirs	Kalihiwai Reservoir	
Capacity (acre-feet / MG)	141 / 46	
Status	Active	
Visual inspection undertaken	Yes	
Irrigation system condition	Poor to Good – see Table 15	
Rehabilitation Potential	Good	
Rehabilitation Cost / CIP	See Table 16	

Table 14
Kalihiwai Irrigation Subsystem
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	184.2
Other Crops	189.0
Grazing	9.8

Table 15
Kalihiwai Irrigation Subsystem
Distribution System Condition

Distribution System	Length (feet)	Comments
Ditches Good Condition	700	
Fair Condition	1,900	Clearing invasive plant species growth
Poor Condition	3,700	Unusable due to heavy invasive species growth
Tunnels		
Good Condition	0	
Fair Condition	1,100	Potential tree root intrusion and/or partial sediment blockage
Poor Condition	700	Collapsed tunnel due to tree root intrusion

The Kalihiwai Ridge Community Association regularly maintains the reservoir and has funded several studies on Kalihiwai Reservoir, including:

- *Simulation of Kalihiwai Reservoir Dam-Break Flooding*, 2006; and
- *Kalihiwai Reservoir Bathymetry Mapping Study* in 2007.

A bathymetric study for the reservoir was performed in 2007 by AquaTechnex, LLC. to determine its storage capacity. The study concluded that the 2007 surface area is 20.78 acres, with a storage capacity of 46.0 MG or 141.2 acre-feet. This volume is much less than previously reported: 90.6 MG or 287 acre-feet.

According to Porter Irrigation staff, there are plans to increase the cultivated area for diversified agricultural use, which will increase water demand. Also, there is a minimum water level established for the Kalihiwai Reservoir due to the use of the water by native water birds, as well as for recreational use by community association members.

Another potential agricultural water demand on this system is from the County of Kaua'i, Kīlauea Agricultural Park. Kīlauea Agricultural Park is across Kūhiō Highway from the Stone Dam and Kalihiwai Irrigation Subsystems. The County has been in informal discussions (circa 2014) with the Porter and Bridgewater Irrigation companies to supply agricultural water to Kīlauea Agricultural Park. The Park was designed to have three (3) wells, each with a 100-gallon-per-minute capacity, and a 300,000-gallon water storage tank.

Kīlauea Agricultural Park has 75 acres of land set aside for agriculture. This land is subdivided into 14 farm lots, ranging from 2.66 acres to 6.93 acres. The anticipated agricultural water demand for 54 acres, at an average use of 6,600 gpd/acre, is equal to pumping approximately 360,000 gpd (250 gallons per minute). The remaining parcels are used for parking, gardens, green waste, and a drainage detention pond.

Exhibit 10. Overgrowth in upper portion of Kalihiwai Ditch

Exhibit 11. Overgrowth in upper portion of Kalihiwai Ditch

Proposed Capital Improvement Projects. Based on the condition survey of Kalihiwai Irrigation Subsystem and information gathered on its various components, the following improvements are proposed. As the water supply issue for Kīlauea Agricultural Park remains undecided, no connection from the Kalihiwai system was included in the CIP. Table 16 presents the proposed CIP, estimated (planning level) costs, and phasing for the proposed improvements.

- Re-establish and reconstruct the upper (mauka) intake from Pohakuhonu Stream to increase water capacity for future agricultural use. The project would entail the reconstruction of the intake, as well as reopening and reconstruction of approximately 3,700 feet of ditch.

- Until recently (circa 2013), there was limited ditch maintenance being performed on the system, due to the lack of maintenance easements and agreements. Unfortunately, this decades-long neglect has allowed plants and invasive species to grow and caused severe damage to the ditch and tunnels. This project requires major clearing of approximately

4,400 feet of ditch segments and tunnels, focusing on clearing overgrowth, replanting of non-invasive species, and rehabilitation/reconstruction.

Table 16
Kalihiwai Irrigation Subsystem
Proposed Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)
	Short-term
Re-establish upper intake	$110,000
Clear ditch sections from overgrowth and rehabilitate ditches and tunnels	$110,000
Establish Kīlauea Agricultural Park water source	To be determined

3.1.2 ANAHOLA DITCH

Ownership and service area information for the Anahola Irrigation System is presented in Table 17. General system information is presented in Table 18. The Anahola Ditch was constructed in the early 1900s by the Makee Sugar Company. By 1933, Līhu‘e Plantation had become the sole owner of Makee Sugar Company and Anahola Irrigation System. At that time, the ditch diverted water from two locations in Anahola Stream. In 2000, Līhu‘e Plantation ended sugar operations, and certain properties were transferred to the State of Hawai‘i. The remaining properties were sold to private owners.

Management and control of the state-owned portion was given to the State of Hawai‘i, Department of Hawaiian Home Lands (DHHL). The ditch alignment sits on both state- and privately owned lands. Due to the different owners, the ditch system was discontinued at the boundary between the two.

Historical USGS records show that average flow during low stream flow months is 3.9 MGD. During high-flow months, the average flow is 6.5 MGD.

For the lower Anahola Ditch, USGS records show an average flow ranging from 0.8 MGD to 2.1 MGD between the low- and high-flow months. Rainfall stations in the Anahola region are currently inactive, with no records after 2000. The station at Kaneha Reservoir had an elevation of 845 feet and a mean annual rainfall of 96.49 inches.

Table 19 presents the land use areas within the DHHL service area, and Table 20 presents the land use areas within the private system. The system maps are shown on Maps 17 to 21:

- Map 17 - Alignments and System Components;
- Map 18 - 2014-2015 Land Use;
- Map 19 - ALISH 1977;
- Map 20 - Land Capability Non-Irrigated Conditions; and
- Map 21 - Land Capability Irrigated Conditions.

Table 17
Anahola Irrigation System
System Ownership and Service Area

Description	Information
Owners	State of Hawaiʻi, DHHL Private owner
Source	Anahola Stream
Estimated Current Water Use (annual average)	610,000 gpd(1) During plantation sugar cane era – estimated at 9 MGD
Estimated Service Area	DHHL – 2,345 acres Private owner – 3,725 acres
Farms Area Served Potential Farming	DHHL - 560 acres Private owner – unverified
Important Agricultural Lands	None

Note: 1) Commission on Water Resource Management

Table 18
Anahola Irrigation System
General System Information

Description	Information	
System Length (feet) / status	4,950 (Active) 36,499 (Inactive) 60,247 (Unverified)	
Reservoirs	DHHL – See Table 21 Private owner – See Table 22	
Intake	Upper Anahola Intake	Lower Anahola Intake
Source	Anahola Stream	Anahola Stream
Hydrologic Unit	Anahola	Anahola
Intake Status	Active	Inactive
Visual inspection undertaken	Yes	
Irrigation system condition	Upper Anahola Ditch – See Tables 23 and 24 Lower Anahola Ditch - Poor Private owner system not surveyed	
Rehabilitation Potential	Upper Anahola Ditch – Good Lower Anahola Ditch – Poor Private owner – To be determined by owner	
Rehabilitation Cost / CIP	DHHL Portion - See Table 25 Private owner – To be determined by owner	

Table 19
Anahola Irrigation System
Land Uses within the Service Area
DHHL Portion

Cultivation	**Area** (acres)
Field Crops	0
Other Crops	248.2
Grazing	309.2

Table 20
Anahola Irrigation System
Land Uses within the Service Area
Private Landowner Portion

Cultivation	**Area** (acres)
Field Crops	106.9
Other Crops	160.9
Grazing	1,729.9

Table 21
Anahola Irrigation System
Reservoir Capacity
DHHL Portion

Reservoir	**DLNR(1) Capacity**		**Capacity(2)**		**Current Status**
	Acre-feet	MG	Acre-feet	MG	
Kaneha	420.0	136.9	--	--	Active
Kanehu #1	105.0	34.2	79.8	26.0	Active
Kanehu #2	146.0	47.6	46.0	15.0	Inactive
Kanehu #3	--	--	--		Active
Upper Anahola	110.0	35.8	82.9	27.0	Active
Lower Anahola	115.0	37.5	153.4	50.0	Active

Notes: 1) DLNR, Dam inventory online database http://dams.hawaii.gov
2) Nishida Souza, Jean, et.al. "*Kealia Agricultural Water System Study on State Owned Lands*," 1996. As referenced in LYON (2014).

Table 22
Anahola Irrigation System
Reservoir Capacity
Private Landowner Portion

Reservoir	Capacity[1]		Current Status
	Acre-feet	MG	
Hala'ula	Unverified		Active
Mimino	70	22.8	Active

Notes: 1) DLNR, Dam inventory online data base. http://dams.hawaii.gov

Assessment of Needs. This assessment of needs only pertains to the DHHL portion of the system, based on a survey conducted in 2015. The condition assessment of the privately owned system was not completed, and the CIP was not developed.

In 2015, only the Upper Anahola Ditch diversion was active, flowing into the Kaneha Reservoir. The condition survey of the DHHL portion rated the intake for the Upper Anahola Ditch to be in fair condition (Exhibit 12). The remainder of the Upper Ditch is disconnected due to split ownership and is in poor condition (Exhibit 13).

The Lower Anahola intake and transmission ditch from Anahola Stream is in even worse condition and may not be feasible for rehabilitation (Exhibits 14 and 15). The single intake on the Upper Anahola Ditch may provide adequate water supply for DHHL needs at this time. A summary of the system's condition is presented in Tables 23 and 24.

In addition, DHHL commissioned two studies on the Anahola Ditch system. In 1996, DHHL completed a limited survey: *Keālia Agricultural Water System Study on State Owned Lands.*[10] The 1996 study included the management and operation of the four regulated dams: 1) Keālia Field 1, 2) Keālia Field 2, 3) Upper Anahola, and 4) Lower Anahola. The second study, *Limited Archaeological & Historical Survey, Anahola Reservoirs Improvement Project*, was performed by Lyon in 2014. The study recommended that the Keālia

[10] Nishida Souza, Jean, et.al. *Kealia Agricultural Water System Study on State Owned Lands*, 1996. As referenced in Lyon (2014).

Field #2 Reservoir and the Lower Anahola Reservoir be decommissioned. The study also recommended the following improvements to the reservoirs:

- Keālia Field #1 Reservoir
    - Reduce lower reservoir capacity to less than 16 MG;
    - Reconstruct existing outlet, including the inlet structure, tunnel, and outlet structure;
    - Partially reconstruct reservoir embankment to provide structural integrity, including adding a rip-rap rock facing on upstream and downstream slopes of the embankment, as well as to the spillway, to prevent erosion;
    - Construct a rip-rap splash pad for the outlet structure; and
    - Construct a maintenance road on the downstream toe of the embankment for ease of access.

Table 23
Anahola Irrigation System
Distribution System Components

Distribution System	Length (feet)	Comments
Ditches		
Active	45	
Inactive	50,556	Majority of the ditches are in poor condition
Unverified	60,437	Private property
Tunnels		
Active	7,863	DHHL property
Inactive	2,919	Majority of the inactive components are on private property
Unverified	11,965	Private property
Flumes		
Active	0	
Inactive	418	Poor condition
Unverified	0	

Table 23 (continued)
Anahola Irrigation System
Distribution System Components

Distribution System	Length (feet)	Comments
Pipelines		
Active	0	
Inactive	0	
Unverified	1,276	Private property
Siphons		
Active	0	
Inactive	0	
Unverified	1,148	Private property

Table 24
Anahola Irrigation System
Distribution System Condition
DHHL and Active Only

Item	Length (feet)
Ditches	
Good Condition	45
Fair Condition	0
Poor Condition	0
Tunnels	
Good Condition	7,863
Fair Condition	0
Poor Condition	0

Exhibit 12. Upper Anahola Intake – Fair Condition

Exhibit 13. Upper Anahola Ditch - Poor Condition

Exhibit 14. Lower Anahola Ditch – Tunnel with root intrusion

Exhibit 15. Lower Anahola Ditch - Fair Condition

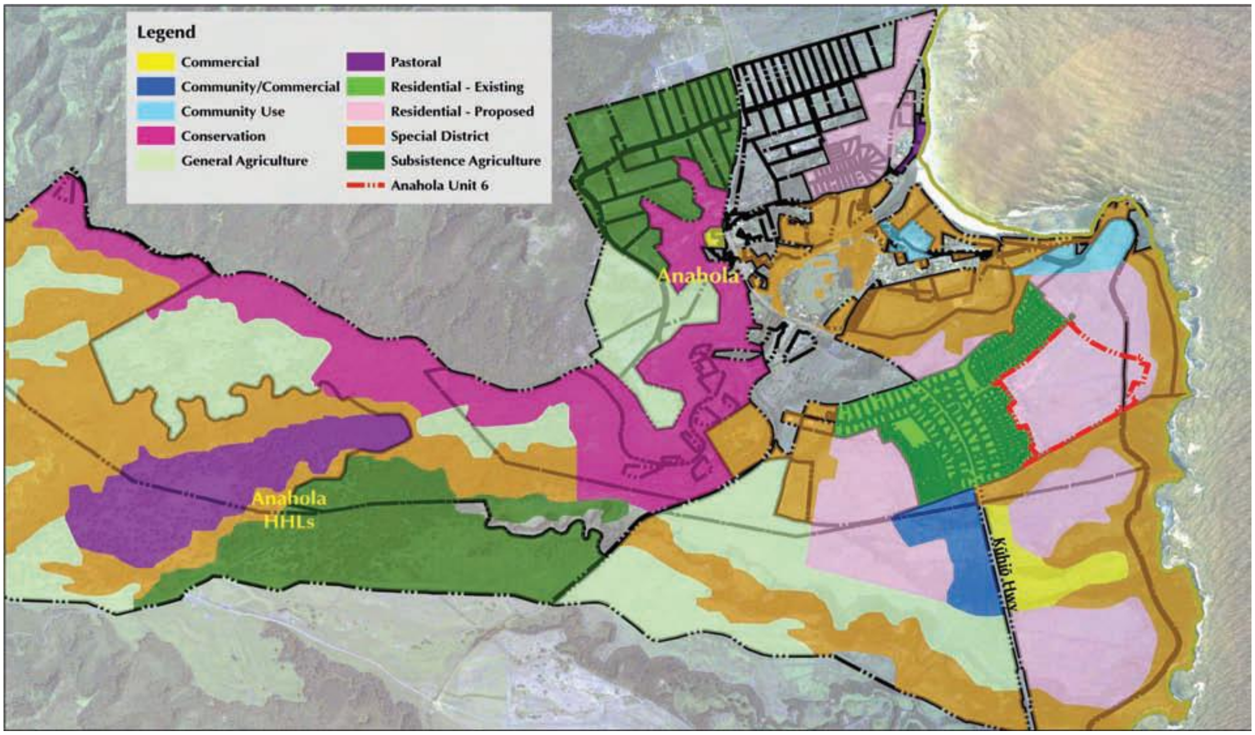

Exhibit 16. DHHL Anahola Regional Plan

- Upper Anahola Reservoir;
  - Reduce lower capacity to less than 16 MG;
  - Reconstruct existing outlet, including the inlet structure, tunnel, and outlet structure;
  - Partially reconstruct reservoir embankment to provide structural integrity, including a rip-rap rock facing on upstream and downstream slopes of the embankment, as well as to the spillway, to prevent erosion;
  - Construct a rip-rap splash pad for the outlet structure; and
  - Construct a maintenance road on the downstream toe of the embankment for ease of access.

In 2010, DHHL prepared a Regional Plan for 4,228 acres in Anahola and Kamalomaloʻo, finding that most lands in Anahola remain undeveloped. The DHHL Regional Plan is based on the concept of "homestead communities." DHHL defines a homestead community as a *Hawaiian community being developed into perpetuity*. Based on the 2010 Plan, DHHL envisions the

Anahola area housing a mixture of cultural, homestead, agriculture, pastoral (grazing), income-generating, and public land uses. Exhibit 16 presents that DHHL plan for the Anahola area.

The 2010 Regional Plan provides the following specific agricultural land uses and acreage:

- Subsistence Agriculture - 103 new 2-acre lots on 292 acres;
- Pastoral (grazing) - (14) 10-acre lots on 148 acres; and
- General Agriculture - 1,108 acres.

The "General Agriculture" areas provide farmers with acreage to develop commercially viable farming operations. These areas are typically flat to gentle rolling hills with good soil. The "Subsistence Agriculture" areas allocate acreage to families who want to supplement their food supply or incomes with farming.

The area has moderate rainfall, and DHHL has plans to develop a water system within the Anahola Agricultural Subdivision. DHHL would like to redevelop the existing irrigation ditch system to provide water to the General Agriculture areas, with the potential to develop hydroelectric power generation plant(s).

Proposed Capital Improvement Projects. Based on the condition assessment of system components and information gathered, a CIP is proposed. Because the original system has been severed, a new pipeline and distribution system should be built to reconnect the tunnel near Kaneha Reservoir to the upper Anahola Reservoir. The proposed CIP program and costs are presented in Table 25 and include the following:

- Rehabilitation/reconstruction of the upper Anahola Stream intake, as well as the tunnel from intake to a new distribution connection point near Kaneha Reservoir;
- Design and construction of a new distribution system from the new connection point near Kaneha Reservoir to the upper Anahola Reservoir. The new distribution system will provide water throughout the DHHL land area for grazing and crop irrigation and should connect to the Kanehu reservoirs. The system will be approximately 7,700 feet in length;

- Planning, design, and construction to rehabilitate upper and lower Anahola reservoirs;
- Planning and design for additional storage, as the existing reservoir capacities were significantly reduced to meet dam and reservoir regulations; and
- Provide funds to study the feasibility of reopening the lower Anahola Ditch irrigation system. This system has the potential to provide a significant amount of water for agricultural uses but is in poor condition.

Table 25
Anahola Irrigation System
Proposed Capital Improvement Projects
DHHL Portion Only

Project Description	**Estimated Cost** (2018 dollars)
	Short-term
Redevelop Upper Anahola Intake and intake tunnel	$550,000
Design and construct new distribution pipeline from intake tunnel to Upper Anahola Reservoir	$8,250,000
Plan, design, and construct rehabilitation of Upper and Lower Anahola Reservoirs	$3,300,000
Plan and create preliminary design for additional storage capacity	$1,100,000
Additional design/construction	To be determined
Study feasibility to open lower Anahola Irrigation system	$400,000

3.1.3 UPPER AND LOWER LĪHUʻE DITCH

Ownership and service area information for the Upper and Lower Līhuʻe Ditch Irrigation System is presented in Table 26. General system information is presented in Table 27.

Initial development of the system was started in 1856 by William Hyde Rice, and continuously expanded until 1937. The Kapahi Tunnel and the Makaleha system were built between 1922 and 1926. In 1926, the Waiahi-ʻIliʻiliʻula-North Wailua ditches were built. By 1931, it is estimated that approximately 79 percent of the Plantation's 6,712 acres was irrigated by gravity flow. The average water demand was estimated at 82 MGD. At that time, the three largest reservoirs were Wailua at 242 million gallons; Upper Kapahi at 30 million gallons; and Lower Kapahi at 25 million gallons. There were two (2) active rainfall stations in the area: one at Puhi, and the other at Līhuʻe Airport. The station at Puhi has an elevation of 330 feet, with a mean annual rainfall of 56.63 inches. The Līhuʻe Airport station has an elevation of 103 feet, with a mean annual rainfall of 39.24 inches.

The land use areas within the service area are presented in Table 28. The service area includes IAL, which is served from both the Līhuʻe and Haʻikū irrigation systems. The total area of the IAL is approximately 11,206 acres, and the agricultural uses of these IAL lands include biomass production for renewable energy and cattle ranching. Irrigation water will be provided by rainfall and water from both the Līhuʻe and Haʻikū Ditch Systems. System maps are shown on Maps 22 to 27.

- Map 22 - Alignments and System Components;
- Map 23 - 2014-2015 Land Use;
- Map 24 - ALISH 1977;
- Map 25 - Land Capability Non-Irrigated Conditions; and
- Map 26 - Land Capability Irrigated Conditions; and
- Map 27 - Important Agricultural Lands.

Table 26
Upper and Lower Līhu'e Ditch System
System Ownership and Service Area

Description	Information
Owners	Grove Farms Company Līhu'e Plantation (System Manager)
Source	Waiahi Stream, Hanamā'ulu Stream and Nāwiliwili Stream
Estimated Current Water Use (annual average)	Unknown
Estimated Service Area	8,048 acres
Farms Served	2,473 acres (estimated) Various crops
Important Agricultural Lands	11,206 acres (Līhu'e and Ha'ikū Ditch Systems)

Table 27
Upper and Lower Līhu'e Ditch System
General System Information

Description	Information		
System Length (feet) / status	75,243 (Unverified)		
Intakes	Intake #27	Intake #45	Stream Diversion
Source (type)	Waiahi Stream (Surface Water)	Hanamā'ulu Stream (Surface Water)	Hanamā'ulu Stream (Surface Water)
Hydrologic Unit	Hanamā'ulu	Hanamā'ulu	Hanamā'ulu
Intake Status	Active	Unverified	Unverified

Table 27 (continued)
Upper and Lower Līhu'e Ditch System
General System Information

Description	Information		
Intakes (continued)	Pipe and Pump	Stream Diversion	Pipe and Pump
Source (type)	Hanamā'ulu Stream (Surface Water)	Nāwiliwili Stream (Surface Water)	Unknown
Hydrologic Unit	Hamamā'ulu	Hamamā'ulu	Hamamā'ulu
Intake Status	Unverified	Unverified	Unverified

Description	Information			
Reservoirs	Kapaia [1]	Aii [1]	Pukakai	Demello
Capacity[1] (acre-feet / MG)	1,114 / 363	68 /22	Unverified	Unverified
Status	Active	Active	Unverified	Active

Description	Information
Visual inspection undertaken	No
Irrigation system condition	Condition assessment was not performed
Rehabilitation Potential	Good (Grove Farm Company)
Rehabilitation Cost / CIP	To be determined by system owner

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov

Table 28
Upper and Lower Līhu'e Ditch System
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	229.1
Other Crops	608.0
Grazing	1,635.6

Assessment of Needs. As a condition assessment was not completed, the CIP was not developed. The private owner is maintaining the system and performing improvements.

3.1.4 UPPER AND LOWER HA'IKŪ DITCH

Ownership and service area information for the Upper and Lower Ha'ikū Ditch Irrigation System is presented in Table 29. General system information is presented in Table 30. The ditch system is privately owned and a subsystem of the Līhu'e Irrigation System.

The Upper and Lower Ha'ikū Ditch System is managed by Līhu'e Plantation. The development of the system started in 1906, with the development of the Kamo'oloa Water Lead. Between 1914 and 1917, Grove Farm built the "Upper Ha'ikū Ditch" on the slopes of Kilohana. The Lower Ha'ikū Ditch was constructed between 1928 to 1948, replacing and realigning the original main ditch with concrete-lined ditches and tunnels. The only active rainfall station in the area is the Halenānaho rainfall station, which sits at an elevation of 490 feet, with a mean annual rainfall of 70.94 inches.

The land use areas within the service area are presented in Table 31. The service area includes IAL, which is served by both the Līhu'e and Ha'ikū irrigation systems. The total area of the IAL is approximately 11,206 acres, and the agricultural uses of these IAL lands include biomass production for renewable energy and cattle ranching. Irrigation water will be provided by rainfall and water from both the Līhu'e and Ha'ikū Ditch Systems. The system maps are shown on Maps 28 to 33 with:

- Map 28 - Alignments and System Components;
- Map 29 - 2014-2015 Land Use;
- Map 30 - ALISH 1977;
- Map 31 - Land Capability Non-Irrigated Conditions;
- Map 32 - Land Capability Irrigated Conditions; and
- Map 33 - Important Agricultural Lands.

Assessment of Needs. As a condition assessment was not completed, the capital improvement program was not developed. The private owner is managing and maintaining the system.

Table 29
Upper and Lower Ha'ikū Ditch System
System Ownership and Service Area

Description	Information
Owners	Grove Farms Company Līhu'e Plantation (System Manager)
Source	See Table 32
Estimated Current Water Use (annual average)	Unknown
Estimated Service Area	8,050 acres
Farms Served	2,938.6 acres
Important Agricultural Lands	11,206 acres (Līhu'e and Ha'ikū Ditch Systems)

Table 30
Upper and Lower Haʻikū Ditch System
General System Information

Description	Information	
System Length (feet) / status	63,599 (unverifed)	
Intakes	See Table 32	
Reservoirs Capacity (acre-feet(1) / MG) Status	Halenānahu 460 / 149.9 Active	Papuaa 921 / 300.1 Active
Visual inspection undertaken	No	
Irrigation system condition	Condition assessment was not performed	
Rehabilitation Potential	Good (Grove Farm Company)	
Rehabilitation Cost / CIP	To be determined by system owner	

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov

Table 31
Upper and Lower Haʻikū Ditch System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	205.4
Other Crops	591.4
Grazing	2,141.8

Table 32
Upper and Lower Haʻikū Ditch System
Intake Description

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion (pump)	Pūʻali	Hamamāʻulu	Used as needed
Stream Diversion	Pūʻali	Hamamāʻulu	Active
Stream Diversion	Pūʻali	Hamamāʻulu	Active
Stream Diversion	Halehaka	Hamamāʻulu	Occasional
Stream Diversion (pump)	Hoʻinakāunalehua	Hamamāʻulu	Unverified
Stream Diversion	Papakōlea	Hamamāʻulu	Unverified
Stream Diversion	Unknown	Hamamāʻulu	Unverified
Stream Diversion	Unknown	Hamamāʻulu	Unverified
Stream Diversion	Unknown (Kula)	Hamamāʻulu	Unverified
Spring	Not applicable	Hamamāʻulu	Unverified
Stream Diversion	Kula	Hamamāʻulu	Unverified
Stream Diversion	Unknown	Hamamāʻulu	Unverified
Stream Diversion	Kamoola	Hamamāʻulu	Active
Stream Diversion	Unnamed	Hamamāʻulu	Unverified
Stream Diversion	Unnamed	Hamamāʻulu	Unverified
Stream Diversion	Kamoola	Hamamāʻulu	Unverified
Stream Diversion	Paohia	Hamamāʻulu	Unverified
Stream Diversion	Paohia	Hamamāʻulu	Unverified
Stream Diversion	Kuʻia	Hamamāʻulu	Unverified
Stream Diversion	Papakōlea	Hamamāʻulu	Unverified
Stream Diversion	Kuʻia	Hamamāʻulu	Active
Stream Diversion	Kamoola	Hamamāʻulu	Active
Stream Diversion	Paohia	Hamamāʻulu	Unverified
Stream Diversion	Unknown	Hamamāʻulu	Unverified
Stream Diversion	Unnamed	Hamamāʻulu	Unverified
Stream Diversion	Unnamed	Hamamāʻulu	Unverified

3.1.5 WAIAHI-KU'IA AQUEDUCT AND KŌLOA-WILCOX DITCH

Ownership and service area information for the Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch Irrigation System is presented in two portions. System information for the portion owned by Grove Farm Company and the Eric A. Knudsen Trust is presented in Table 33, and the portion owned by Alexander & Baldwin (A&B), known as the Lāwa'i area, is presented in Table 34. General information for the Grove Farm Company and E. A. Knudsen Trust portion is presented in Table 35, and for the Lāwa'i area in Table 36.

Kōloa Plantation, established in 1835 by Ladd & Co., is known as Hawai'i's first sugar plantation. In 1848, Grove Farm Company bought Ladd & Co. at an auction and later sold the plantation to McBryde Sugar Company. In 1899, McBryde Sugar Company incorporated with McBryde Estate and 'Ele'ele Plantation. The incorporation transferred ownership and management of the Lāwa'i and Kōloa portion of the system to the McBryde Sugar Company. In 1910, A&B became an agent, or shareholder, in McBryde Sugar Company, and later A&B bought out the remaining partners. In 1948, Kōloa Plantation, along with its mill, was acquired by Grove Farm.

The first segment of Wilcox Ditch was probably dug during the drought year of 1869. In 1885, Wilcox Ditch was extended to deliver water to an additional 200 acres of sugar cane. The estimated capacity of the Wilcox Ditch was eight (8) MGD, with an estimated average daily flow of about four (4) MGD. Kōloa Plantation completed the construction of the Waita Reservoir in 1931, with a 2.3 billion gallon storage capacity.

From 1908 to 1909, there was the "McBryde-Kōloa War" over the water rights to 'Ōma'o Stream, between Kōloa Plantation Company and McBryde Sugar Company. McBryde Sugar Company claimed to own the rights to the water in 'Ōma'o Stream and stopped the water running to Kōloa Plantation Company, a longtime user of the 'Ōma'o Stream's water. During the "war," dams were removed/destroyed and rebuilt. Guards were posted to protect the rebuilt dams.

USGS records show that the estimated average flow through the Waiahi-Ku'ia system during low-flow months was 1.6 MGD and during high-flow months was 7.8 MGD. The same records show the estimated average flow through the Kōloa-Wilcox system was 7.1 MGD during low-flow months and 18.1 MGD during high-flow months. There are five rainfall stations active in the area: Kōloa Mauka, Kōloa, Māhā'ulepū, East Lāwa'i and Kukui'ula. Table 37 presents the elevation and mean annual rainfall of these stations.

The large water storage capacity available at Waita Reservoir allowed Kōloa Plantation to irrigate over 70 percent of its fields with water from mountain sources. The water for the Kōloa Reservoir was supplied through the modest Wilcox Ditch. In 1914, Līhu'e Plantation built the Waiahi-Ku'ia Aqueduct, also known as the Kōloa Ditch. This allowed water transmission from Waiahi and Ku'ia streams over Grove Farm lands into Waita Reservoir, via the Wilcox Ditch.

The Kōloa-Wilcox Ditch is 3.3 miles long, with the following major components: 14,685 feet of tunnels, with the longest tunnel having a length of 5,845 feet; 467 feet of flumes; and 2,320 feet of ditches. The design capacity was estimated to be 100 MGD, but the actual average daily flow was approximately 65 MGD.

The service area includes IAL, owned by Māhā'ulepū Farm LLC. The total area of the IAL is approximately 1,533 acres, and the agricultural uses include taro, seed corn, and forage crops for cattle ranching. Anticipated water use presented in the associated IAL Petition and Decision and Order is 2.4 MGD. Land use acreage within the service area is presented in Table 38. The system maps are shown on Maps 34 to 39, as follows:

- Map 34 - Alignments and System Components;
- Map 34A - Alignments and System Components Detailed View;
- Map 35 - 2014-2015 Land Use;
- Map 36 - ALISH 1977;
- Map 37 - Land Capability Non-Irrigated Conditions;
- Map 38 - Land Capability Irrigated Conditions; and
- Map 39 - Important Agricultural Lands.

Table 33
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
System Ownership and Service Area
(without the Lāwa'i Portion)

Description	Information
Owners	Grove Farm Company Eric A. Knudsen Trust
Source	Various streams and tunnels
Estimated Current Water Use (annual average)	McBryde area only, see Table 39
Estimated Service Area	11,787 acres
Farms Served	Unverified
Important Agricultural Lands	None

Table 34
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
System Ownership and Service Area
(Lāwa'i Portion)

Description	Information
Owners	Alexander and Baldwin, Inc.
Source	Nalohia Stream
Estimated Current Water Use (annual average)	Unverified
Estimated Service Area	11,787 acres
Farms Served	2,939 acres (estimated)
Important Agricultural Lands	Yes

Table 35
Waiahi-Kuʻia Aqueduct and Kōloa-Wilcox Ditch System
General System Information
(without the Lāwaʻi Portion)

Description	Information			
System Length (feet) / status	54,598 (Active) 27,875 (Inactive) 394,199 (Unverified)			
Intakes	See Table 40			
Reservoirs Capacity (acre-feet)(2) / MG Status	ʻŌmaʻo 194 / 63 Active	Papuaa 921 / 300 Active	Waita 9,900 / 3,226 Active	Mauka 345 / 112 Active
Reservoirs Capacity (acre-feet)(1) / MG Status	Puu O Hewa 115 / 385 Active	Piwai 261 / 85 Active	Pia Mill 39 / 13 Active	
Visual inspection undertaken	No			
Irrigation system condition	Condition assessment was not performed			
Rehabilitation Potential	Good (Grove Farm Company and Eric A. Knudsen Trust)			
Rehabilitation Cost / CIP	To be determined by system owner			

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov

Table 36
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
General System Information
(Lāwa'i Portion)

Description	Information				
System Length (feet) / status	22,762 (Active) 32,073 (Inactive)				
Intakes Source (type) Hydrologic Unit Intake Status	Intake Nalohia Stream (Surface Water) Kōloa Active				
Reservoirs	Hanini	Huinawai	Aepoalua	Aepo	
Capacity (acre-feet(1) / MG)	Unknown	196 / 64	131 / 43	457 / 149	
Status	Active	Active	Active (2)	Active (3)	
Reservoirs	Aepoekolu	Aepoeha	Manuhonuhonu		
Capacity(1) (acre-feet / MG)	152 / 50	670 / 218	49 / 16		
Status	Active (4)	Active	Active (4)		
Reservoirs	Kaupale	Kūmano			
Capacity(1) (acre-feet / MG)	240 / 78	175 / 57			
Status	Active (4)	Active (2)			
Visual inspection undertaken	Yes				
Irrigation system condition	Good See Tables 41 and 42				
Rehabilitation Potential	Good				
Rehabilitation Cost / CIP	See Table 43				

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov
2) Aepoalua Reservoir used as a stormwater collection basin.
3) Aepo Reservoir also used for emergency purposes.
4) To be decommissioned as of 2014.

Table 37
Waiahi-Kuʻia Aqueduct and Kōloa-Wilcox Ditch System
Rainfall Summary

Station	Elevation (feet)	Mean Annual Rainfall (inches)
Kōloa Mauka	640	96.31
Kōloa	240	56.78
Māhāʻulepū	80	44.13
East Lāwaʻi	440	54.60
Kukuʻiula	105	42.09

Table 38
Waiahi-Kuʻia Aqueduct and Kōloa-Wilcox Ditch System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	889.2
Other Crops	1,501.4
Grazing	2,871.0

Table 39
Waiahi-Kuʻia Aqueduct and Kōloa-Wilcox Ditch System
Reported Flows for McBryde Resources

Gage Name	Mean (MGD)	Minimum (MGD)	Maximum (MGD)
Alexander	5.92	0	8.52
Wainiha	75.24	0	446.10
Lāwaʻi	0.73	0	1.91

Reference: CWRM (2017).

Table 40
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
Intake Description
(Without the Lāwa'i Portion)

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion	Palikea	Kōloa	Unverified
Stream Diversion	Waiahi	Kōloa	Active
Stream Diversion	'Ili'ili'ula	Kōloa	Active
Stream Diversion	'Ili'ili'ula	Kōloa	Active
Stream Diversion	Waikoko	Kōloa	Active
Stream Diversion	Wailua	Kōloa	Unverified
Stream Diversion	Waiahi	Kōloa	Active
Stream Diversion	'Ili'ili'ula	Kōloa	Active
Stream Diversion	'Ili'ili'ula	Kōloa	Active
Stream Diversion	Waiahi	Kōloa	Active
Stream Diversion	Waiaka	Kōloa	Active
Stream Diversion	Waiahi	Kōloa	Active
Tunnel	Not applicable	Kōloa	Unverified
Tunnel	Not applicable	Kōloa	Unverified
Stream Diversion	Unknown	Unknown	Unverified
Stream Diversion	Ku'ia	Kōloa	Unverified
Stream Diversion	Kamoola	Kōloa	Unverified
Stream Diversion	Kamoola	Kōloa	Unverified
Stream Diversion	Paohia	Kōloa	Unverified
Stream Diversion	Paohia	Kōloa	Unverified
Stream Diversion	Ku'ia	Kōloa	Unverified
Stream Diversion	Ku'ia	Kōloa	Active
Stream Diversion	Kamoola	Kōloa	Active
Stream Diversion	Paohia	Unknown	Unverified
Stream Diversion	Unknown	Unknown	Unverified
Stream Diversion	Paeleele	Kōloa	Unverified
Stream Diversion	'Ōma'o	Unknown	Active
Stream Diversion	'Ōma'o	Unnamed	Active

Table 40 (continued)
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
Intake Description
(Without the Lāwa'i Portion)

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion	Poeleele	Unknown	Active
Spring	Hakaka spring	Kōloa	Unverified
Stream Diversion	Waihohonu	Kōloa	Unverified
Spring	Not applicable	Kōloa	Unverified
Stream Diversion	Unnamed	Kōloa	Unverified
Stream Diversion	Waihohonu	Kōloa	Unverified
Stream Diversion	Unnamed	Kōloa	Unverified
Stream Diversion	Waihohonu	Kōloa	Unverified

Assessment of Needs. As a condition assessment was not completed for the non-A&B portion of the system, a capital improvement program was not developed. A private owner is managing and maintaining that portion of the system.

This assessment of needs for the A&B (Lāwa'i) portion of the system and survey was conducted in 2014. The system is currently in use, in good condition, and being maintained by A&B. Tables 41 and 42 show the system components and their respective status.

The "original" A&B portion of the system that is north (mauka) of Huinawai reservoir was observed and is in good condition. Exhibits 17 and 18 show examples of the condition of the Lāwa'i system. The irrigation system south (makai) of Huinawai reservoir was replaced by two pipelines: one with an 18-inch diameter, and the other with a 12-inch diameter. The 18-inch pipeline provides water to the coffee fields above (mauka) A&B's Kuku'iula Development, while the 12-inch pipeline services A&B's Agriculture Park. The approximate alignment of the two pipelines are shown in Map 34. The Agriculture Park has an area of 220 acres, with 20 tenant lots ranging from 10 to 20 acres. The tenants cultivate a variety of commodities, from nursery plants to truck crops (mixed produce). In the areas used for cattle ranching, the water is provided on an as-needed basis and pumped from the nearest reservoir.

Table 41
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System Distribution System Components
(Lāwa'i Portion Only)

Distribution System	Length (feet)	Comments
Ditches		
Active	4,881	
Inactive	28,356	Replaced with a pipeline system that follows parts of the ditch
Tunnels		
Active	1,713	
Inactive	3,430	Replaced with pipeline system
Siphons		
Active	0	
Inactive	287	Replaced with pipeline system
Pipelines		
Active	16,168	Estimated length
Inactive	0	

Table 42
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
Distribution System Condition
(Lāwa'i Portion and Active Only)

Distribution System	**Length** (feet)	**Comments**
Ditches		
Good Condition	4,881	North of Huinawai Reservoir only
Fair Condition	0	
Poor Condition	0	
Tunnels		
Good Condition	1,713	North of Huinawai Reservoir only
Fair Condition	0	
Poor Condition	0	
Pipelines		
Good Condition	16,168	
Fair Condition	0	
Poor Condition	0	

Exhibit 17. Lāwa'i Portion - Lined Ditch Section

Exhibit 18. Lāwa'i Portion - Tunnel Entrance

Proposed Capital Improvement Projects. Based on the condition survey and discussions with A&B staff, the following two projects are proposed. Table 43 presents the proposed CIP, estimated costs (planning level), and phase for development.

- The ditch north of Kaumuali'i Highway (Highway 50) is impacted by invasive species overgrowth. This overgrowth requires continuous (daily) maintenance, resulting in staff and repair costs to mitigate bank erosion, flow blockages, and reduced flow. The invasive species overgrowth needs to be cleared and the area re-planted to minimize the impact on the irrigation ditch and provide erosion control. The approximate area to be cleared and re-planted is one (1) acre and is on sloped terrain.

- The outlet from Huinawai Reservoir has a leak and requires renovation. The renovation may require a portion of the dam to be reconstructed to provide a long-term solution to the problem.

Table 43
Waiahi-Ku'ia Aqueduct and Kōloa-Wilcox Ditch System
Proposed Capital Improvement Projects
(Lāwa'i Portion Only)

Project Description	**ESTIMATED COST** (2018 dollars)
	Short-term
Invasive species removal and revegetation (Planning, design, and construction)	$800,000
Renovation of dam at outlet	
Planning and design	$550,000
Construction	To be determined

Note: construction cost to be determined after design is completed.

3.1.6 OLOKELE DITCH

Ownership and service area information for the Olokele Ditch Irrigation System is presented in Table 44. General system information is presented in Table 45. There is one rainfall station in the area: the Makeweli rainfall station at an elevation of 140 feet, with a mean annual rainfall of 22.24 inches.

The Olokele Ditch was opened in 1904 as part of the expansion plans for Makaweli Plantation. The Olokele irrigation system marked the first time that long tunnels were used instead of open ditches, under the design and direction of Michael M. O'Shaughnessy, who was considered one of the world's foremost irrigation engineers. This undertaking was estimated to cost $500,000. The successful development of water diversion for Makaweli Plantation (later known as Olokele Sugar Company) led to the "Hanapēpē Case."[11] The "Hanapēpē Case" resulted in a landmark 1973 Supreme Court decision, now known as the McBryde decision.

The land use areas within the service area are presented in Table 46. The IAL area is approximately 20,888 acres and will be used primarily for cattle ranching. The system maps are shown on Maps 40 to 45, as follows:

- Map 40 - Alignments and System Components;
- Map 41 - 2014-2015 Land Use;
- Map 42 - ALISH 1977;
- Map 43 - Land Capability Non-Irrigated Conditions;
- Map 44 - Land Capability Irrigated Conditions; and
- Map 45 - Important Agricultural Lands.

Assessment of Needs. As a condition assessment was not completed, the CIP was not developed. However, telephone conversations with the owner's representatives indicate that the owners are maintaining the ditch system and there are adequate water resources for farmers.

[11] Lawsuit filed by McBryde Sugar Company against Gay and Robinson regarding downstream water users.

Table 44
Olokele Ditch System
System Ownership and Service Area

Description	Information
Owners	Gay and Robinson
Source	Various streams, see Table 47
Estimated Current Water Use (annual average)	Historical – 66 MGD
Estimated Service Area	15,730 acres
Farms Served	Unverified
Important Agricultural Lands	20,888 acres

Table 45
Olokele Ditch System
General System Information

Description	Information
System Length (feet)/status	201,136 (unverified)
Intakes	See Table 47
Reservoirs	See Table 48
Visual inspection undertaken	No
Irrigation system condition	Condition assessment was not performed
Rehabilitation Potential	Good, as system is active
Rehabilitation Cost / CIP	To be determined by system owner

Table 46
Olokele Ditch System
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	7,472.4
Other Crops	933.6
Grazing	1,384.8

Table 47
Olokele Ditch System
Intake Description

Intake Type	**Stream**	**Hydrologic Unit**	**Status**
Stream Diversion	Waikai	Makaweli	Unverified
Stream Diversion	Hanonui	Makaweli	Unverified
Stream Diversion	Paliemo	Makaweli	Unverified
Stream Diversion	Manawaiopuna	Makaweli	Unverified
Stream Diversion	Lana	Makaweli	Unverified
Stream Diversion	Kala	Makaweli	Unverified
Stream Diversion	Maku	Makaweli	Unverified
Stream Diversion	Kunalele	Makaweli	Unverified
Stream Diversion	Hikilei	Makaweli	Unverified
Stream Diversion	Kunalele	Makaweli	Unverified
Stream Diversion	Mahaikona	Makaweli	Unverified
Stream Diversion	Kalopopo	Makaweli	Unverified
Stream Diversion	Kaluawai	Makaweli	Unverified
Stream Diversion	Waiānuenue	Makaweli	Unverified
Stream Diversion	Kalopopo	Makaweli	Unverified
Stream Diversion	Olokele	Makaweli	Unverified

Table 48
Olokele Ditch System
Reservoir Capacity

Reservoir	Capacity(1)		Current Status
	Acre-feet	MG	
Waikaia	--	--	Unverified
Po'opueo	--	--	Unverified
Waikoloi	147	47.9	Active
Pu'ulani	--	--	Unverified
Kuhumu	--	--	Unverified
Waikai	--	--	Unverified
Kaawanui	110	35.8	Active
Kalaeloa	--	--	Unverified
Waikaia	58	18.9	Active
'A'aka	--	--	Unverified
Kepani	85	27.7	Active

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov

3.2 O'AHU IRRIGATION SYSTEMS

The following systems were studied on O'ahu, in the City and County of Honolulu, and their locations are shown in Exhibit 19.

- O'ahu Ditch (Wahiawā, Helemano, Tanada, and Ito).
- Opaeula and Kamananui.
- Kahuku Irrigation System.
- Galbraith Lands Irrigation System.

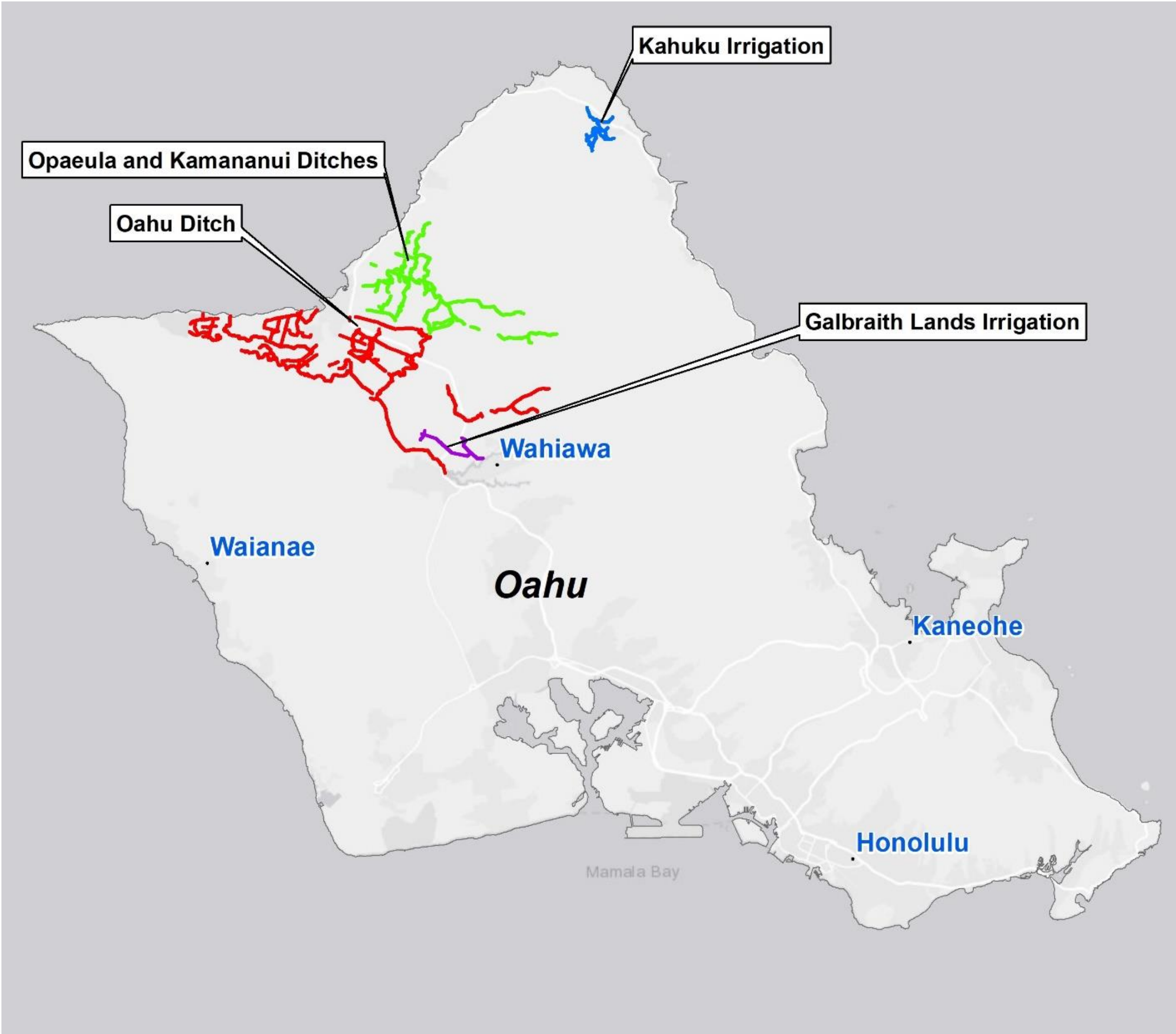

Exhibit 19. Water Systems Inventoried on O‘ahu

3.2.1 O‘AHU (MAUKA DITCH TUNNEL), WAHIAWĀ, HELEMANO, TANADA, AND ITO DITCHES

Ownership and service area information for the O‘ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch Irrigation Systems is presented in Table 49. General system information is presented in Table 50.

The irrigation network was developed by Waialua Sugar Company[12] and was comprised of seven (7) major systems: O‘ahu (Mauka Ditch Tunnel),

[12] Waialua Sugar Company was a subsidiary of Dole Food Co., Inc.

Wahiawā, Helemano, Tanada, Opaeula, Kamananui, and Ito Ditch. While Waialua Sugar Company was operating, these ditch systems were interconnected and had the flexibility to meet water demands of the production areas.

Upon the closure of Waialua Sugar Company, the system was separated into two different owners: 1) Dole Company and 2) Kamehameha Schools Bishop Estates (KSBE). This section will discuss the O'ahu Ditch (Dole) system, which includes O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditches. Four (4) surface-water collection systems (Wahiawā, Helemano, Opaeula, and Kamananui) were built between 1900 and 1906. The exact dates of construction for the Helemano and Poamoho Ditch sections are not known, but reports indicate that these ditches were completed circa 1902-1904. The Tanada Ditch was designed for larger flows, but records indicate that the average flow was approximately three (3) MGD. The Ito Ditch was built sometime after 1911.

Historical USGS data states that the estimated average flow in the O'ahu System during low-flow months is 2.3 MGD, rising to 3.0 MGD during high-flow months. Historical USGS data states that the estimated average flow in the Wahiawā System during low-flow months is 6.5 MGD, increasing to 12.3 MGD during high-flow months. The Upper Wahiawā rainfall station has an elevation of 1,115 feet and a mean annual rainfall of 59.60 inches.

Since 1927, Lake Wilson has received treated effluent from the City and County of Honolulu through the Wahiawā Wastewater Treatment Plant (WWTP). In addition, the system receives treated effluent from the U.S. Army Schofield Barracks WWTP downstream of Lake Wilson.

Within the O'ahu Ditch irrigation system service area, there are 679.432 acres of IAL, with 242.085 acres in Waialua, 205.593 acres in Whitmore, and 231.754 acres in Mililani South. The IAL will be used for cultivating diversified crops such as pineapple, plumeria, bananas, mango, star fruit, 'a'ali'i, bromeliads, cacao, 'iliahi, koa, lychee, moa, 'ōhi'a lehua, papaya, rambutan, ti leaf, herbs, vegetables, ornamental shrubs, grass, and tuberose. Anticipated water use from the associated IAL Petition and Decision and Order is approximately 2.1 MGD. The land use areas within the service area are shown in Table 51. The O'ahu Ditch system maps are shown on Maps 46 to 51, as follows:

- Map 46 - Alignments and System Components;
- Map 47 - 2014-2015 Land Use;
- Map 48 - ALISH 1977;
- Map 49 - Land Capability Non-Irrigated Conditions;
- Map 50 - Land Capability Irrigated Conditions; and
- Map 51 - Important Agricultural Lands.

Table 49
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
System Ownership and Service Area

Description	Information
Owners	Dole Company
Source	Kaukonahua, Helemano and Paukaulia streams and springs
Estimated Current Water Use (annual average)	10 MGD Reported flows, see Table 52
Estimated Service Area	24,640 acres
Farms Served (estimated)	11,500 acres 18 commercial farms (2007)
Important Agricultural Lands	679 acres

Table 50
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
General System Information

Description	Information		
System Length (feet) / status	135,366 (active) 185,069 (inactive) 9,138 (unverified)		
Intake	Stream (with pump)	Stream	Spring
Source (type)	Kaukonahua (Surface Water)	Helemano (Surface Water)	Spring (Surface Water)
Hydrologic Unit	Wahiawā	Wahiawā	Wahiawā
Intake Status	Stream Diversion - Active Pump - Unverified	Active	Inactive
Intake	Spring	Stream	Spring
Source (type)	Spring Spring	Paukaulia (Surface water)	Spring Spring
Hydrologic Unit	Wahiawā	Wahiawā	Wahiawā
Intake Status	Inactive	Inactive	Inactive
Reservoirs	See Table 53		
Visual inspection undertaken	Yes		
Irrigation system condition	See Tables 54 and 55		
Rehabilitation Potential	Good		
Rehabilitation Cost / CIP (five years)	$8,360,000 (See Table 56)		

Table 51
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	4,601.8
Other Crops	4,313.3
Grazing	1,590.2

Table 52
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
Reported Flows
(MGD)

Gage	**2015**			**2016**			**2017**		
	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max
Helemano	2.1	0.7	3.1	1.8	0.9	2.2	1.9	0.8	2.5
Wahiawā	5.4	3.9	8.0	9.0	5.7	11.4	7.6	5.7	9.4

Reference: CWRM (2017)

Assessment of Needs. A survey of the O'ahu Ditch system (including the other systems) provided data for the condition analysis. The system components and their assessed condition are shown in Tables 54 and 55. Exhibits 20-23 are examples of the various conditions found along O'ahu Ditch. The pipe, siphon, and tunnel lengths represent horizontal lengths; actual lengths will be longer, as dictated by terrain. Many of the inactive ditches within the O'ahu Ditch, especially in the Waialua area, are in fair condition and used to capture, store, and/or divert storm water runoff.

In 2008, the Hawai'i Department of Agriculture, Agricultural Development Corporation (ADC) published the *Wahiawā Irrigation System, Economic*

Impact Study.[13] The study focused on Waialua Sugar Company lands that were in Haleʻiwa, Waialua, Poamoho, and north of Poamoho. By 1996, near the end of sugar production at Waialua Sugar Company, approximately 10 MGD was flowing through the system to irrigate approximately 6,400 acres of agriculture land, or approximately 55 percent of the total farmable land.

Table 53
Oʻahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System Reservoir Capacity

Reservoir	Capacity(1)		Current Status
	Acre-feet	MG	
Upper Helemano	700	228	Active
Wahiawā (Lake Wilson)	9,200	2,998	Active
Kemoo 5	63	21	Active
Kemoo 8	29	10	Active
Kemoo 2A	23	8	Active
Ranch 1	--	--	Decommissioned
Ranch 4	--	--	Decommissioned
Ranch 10A	--	--	Decommissioned
Ranch 10B	35	11	Active
Kaheaka	27	9	Active
Helemano 2A	27	9	Unverified
Helemano 6	80	26	Active
Helemano 10	--	--	Decommissioned
Helemano 11	--	--	Decommissioned
Helemano 16	65	21	Active

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov/

According to the 2008 ADC study, there are 8,100 acres of agricultural land within the service area, of which 6,400 acres depend on irrigation. Of the 6,400 acres, approximately 45 percent is currently not being farmed (non-

[13] Southichack, Mana K., *Wahiawā Irrigation System, Economic Impact Study*, November 21, 2008.

arable) for various reasons, including topography, water, etc. According to the ADC study, approximately 1,715 acres of these non-arable lands could be converted to cultivation if irrigated.

Table 54
Oʻahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
Distribution System Components

Distribution System	**Length** (feet)	**Comments**
Ditches		
Active	65,770	Inactive ditches are used to control and store storm water runoff
Inactive	152,140	
Pipelines		
Active	14,110	Estimated length
Inactive	22,060	
Flumes		
Active	750	
Inactive	250	
Siphons		
Active	5,660	Horizontal length
Inactive	2,250	
Tunnels		
Active	32,160	Estimated length
Inactive	5,840	
Canals		
Inactive	1,000	

Table 55
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
Distribution System Condition
(Active Components Only)

Distribution System	**Length** (feet)	**Comments**
Ditches		
Good Condition	54,520	
Fair Condition	9,760	Ditch along highway should be enclosed or replaced with pipeline
Poor Condition	1,490	
Pipelines		
Good Condition	13,970	
Fair Condition	120	Visual inspection for leaks
Poor Condition	10	
Siphons		
Good Condition	1,300	
Fair - Poor Condition	4,360	Leaking and aging
Tunnels		
Good Condition	32,160	Portions have minor root intrusion, which may cause damage in the future
Fair Condition	0	
Poor Condition	0	

Exhibit 20. O'ahu Ditch - Damaged siphon

Exhibit 21. O'ahu Ditch - Poor condition

Exhibit 22. O'ahu Ditch - Good condition

Exhibit 23. O'ahu Ditch - Ditch collapse

Proposed Capital Improvement Projects. Based on the 2014 assessment of O'ahu Ditch (Dole portion), which includes the O'ahu, Helemano, Wahiawā, Tanada, and Ito ditches, and information gathered from stakeholders, a CIP is proposed. The following projects are proposed, and estimated costs and construction phasing are presented in Table 56.

- Repair ditch damaged by age and/or plant and animal intrusion. Approximately 11,230 feet of ditch needs repair.
- Install pipelines in ditches adjacent to highways, roadways, and near public access driveways to reduce blockage caused by embankment collapse or rubbish accumulation. Some embankments near ditches may require retaining walls to be stabilized. Approximately 700 feet of ditch should be replaced with pipelines.
- Rehabilitate or replace leaking and aged siphons. The use of slip-lining or cured-in-place technologies to rehabilitate the existing siphons should be considered. There are five (5) leaking siphons with a total horizontal length of 4,360 feet.

Table 56
O'ahu (Mauka Ditch Tunnel), Wahiawā, Helemano, Tanada, and Ito Ditch System
Proposed Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)
	Short-Term
Repair ditches	$2,100,000
Install pipelines	
Investigation	$500,000
Design and Construction	To be determined
Rehabilitate siphons	$5,700,000
Bathymetry study	$60,000

- Perform a bathymetry study on Helemano Reservoir. As the system has been operating for over a century, the sediment buildup in the reservoir has reduced its storage capacity. Therefore, a bathymetry study is recommended to determine the reduced capacity and to analyze the feasibility of having the reservoir dredged to increase storage capacity.

3.2.2 OPAEULA AND KAMANANUI SYSTEMS

This section discusses the KSBE System, comprising the Opaeula and Kamananui ditch systems. Ownership and service area information for the Opaeula and Kamananui irrigation systems is presented in Table 57. General system information is presented in Table 58. This system was once connected to the other O'ahu ditch systems during the operation of Waialua Sugar Company.

There are two (2) rainfall stations for this area. The Opaeula rainfall station is located at an elevation of 1,060 feet and has a mean annual rainfall of 56.82 inches. The Pūpūkea Road rainfall station is located at an elevation of 1,160 feet and has a mean annual rainfall of 75.44 inches.

Within the KSBE irrigation system (Opaeula and Kamananui) service area, there are 9,171 acres of IAL, with 6,488.497 acres in the Kamananui service area and 2,683 acres in the Opaeula service area. The IAL lands contain approximately 722 acres planted with diversified agriculture such as corn, banana, taro, papaya, mango, and lettuce; 297 acres used for livestock; and one (1) acre planted with koa as a windbreak. The land above the 600-foot elevation is occupied by 30 wind turbines. Table 59 presents the land use areas within the service area. The overall system is shown on Maps 52 to 57:

- Map 52 - Alignments and System Components;
- Map 53 - 2014-2015 Land Use;
- Map 54 - ALISH 1977;
- Map 55 - Land Capability Non-Irrigated Conditions;
- Map 56 - Land Capability Irrigated Conditions; and
- Map 57 - Important Agricultural Land.

Table 57
Opaeula and Kamananui Irrigation System
System Ownership and Service Area

Description	Information
Owners	Kamehameha School Bishop Estate
Source	Various streams
Estimated Current Water Use (annual average)	Unverified
Estimated Service Area	9,350 acres
Farms Served	4,500 acres
Important Agricultural Lands	9,171 acres

Table 58
Opaeula and Kamananui Irrigation System
General System Information

Description	Information
System Length (feet) / status	164,952 (unverified)
Intakes	See Table 60
Reservoirs	See Table 61
Visual inspection undertaken	No
Irrigation system condition	Working and active
Rehabilitation Potential	Good
Rehabilitation Cost / CIP	To be determined by owner

Table 59
Opaeula and Kamananui Irrigation System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	158.2
Other Crops	1,575.4
Grazing	2,719.2

Table 60
Opaeula and Kamananui Irrigation System
Intake Description

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion	Opaeula	North	Unverified
Stream Diversion	Kawaiiki	North	Unverified
Stream Diversion	Waimea	North	Active*
Stream Diversion	Ka`alaea	North	Active*
Stream Diversion	Kawailoa	North	Active*
Stream Diversion	Laniākea	North	Active*
Stream Diversion	Anahulu	North	Active*
Spring	--	North	Active

* Information from the KSBE IAL petition.

Table 61
Opaeula and Kamananui Irrigation System
Reservoir Capacity

Reservoir	Capacity (1)		Current Status
	Acre-feet	MG	
Opaeula 1	320	104	Active
Opaeula 2	75	24	Decommissioned
Opaeula 5	30	10	Unverified
Opaeula 8	39	13	Unverified
Opaeula 15	74	24	Unverified
Opaeula 16	85	28	Active
Kawailoa 3	33	11	Unverified
Kawailoa 7	63	21	Unverified
Kawailoa 8	11	4	Unverified
Kawailoa 9	27	9	Unverified
Kawailoa 11	20	7	Unverified
Kawailoa 14	63	21	Unverified
Kawailoa 15	23	8	Unverified
Kawailoa 18	44	14	Unverified

Notes: 1) DLNR, Dam inventory online database. http://dams.hawaii.gov/

Assessment of Needs. As a condition assessment was not completed, a capital improvement program was not developed. The Opaeula and Kamananui System (KSBE System) is privately owned and currently active. Based on discussions with system users, the system is active and has a water management system in place to schedule irrigation times for farmers. Future uses include diversified agriculture and wind and photovoltaic energy farms.

3.2.3 KAHUKU IRRIGATION SYSTEM

Ownership and service area information for Kahuku Irrigation System is presented in Table 62. General system information is presented in Table 63. The system was developed and managed by HDOA-ARMD within the Kahuku Agricultural Park, Kahuku, O'ahu. The system is an underground pipeline system. In addition, discussions with HDOA-ARMD staff provided insight to issues, flows, and land use.

Table 62
Kahuku Irrigation System
System Ownership and Service Area

Description	Information
Owners	State of Hawai'i HDOA–ARMD (System Manager)
Source:	Groundwater
Estimated Current Water Use (annual average)	6,000 gpd/acre for nursery use (planned) 4,000 gpd/acre for truck farms (planned)
Estimated Service Area	225 acres
Farms Served	24 farms
Important Agricultural Lands	None

Table 63
Kahuku Irrigation System
General System Information

Description	Information
System Length (feet)/Status	12,000 (active)
Intake Source (type) Hydrologic Unit Intake Status	Wells Groundwater Koʻolauloa Active
Reservoirs Capacity Status	Water tank 0.10 million gallons Active
Visual inspection undertaken	Yes
Irrigation system condition	Good, see Table 65
Rehabilitation Potential	Good
Rehabilitation Cost / CIP (five years)	$4,370,000 See Table 66

There is one rainfall station in the area: the Kiʻi-Kahuku (Pump 5) rainfall station at an elevation of 40 feet, with a mean annual rainfall of 43.97 inches. Table 64 presents the land use acreages within the service area. The system maps are shown on Maps 58 to 62, as follows:

- Map 58 - Alignments and System Components;
- Map 59 - 2014-2015 Land Use;
- Map 60 - ALISH 1977;
- Map 61 - Land Capability Non-Irrigated Conditions; and
- Map 62 - Land Capability Irrigated Conditions.

Table 64
Kahuku Irrigation System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	0.0
Other Crops	197.8
Grazing	0.0

Assessment of Needs. Visual inspection of the system identified the pump house as a potential project, but there were no leaks in the distribution system. The pump house is deteriorating due to environmental conditions in the area. A summary of the inspection is presented in Table 65, and Exhibits 24 and 25 show the pumps and water tank, respectively.

Kahuku Agricultural Park is located west of Kahuku town and adjacent to the land used by Kahuku Farmers Association. The Kahuku Irrigation System supplies water to 24 agriculture lots covering approximately 225 acres. Of the 225 acres, there are approximately 160 acres of relatively flat lands (slopes < 10 percent) that were designated for truck farming. The remaining acreage is poorer land, with varying slopes, some greater than 10 percent, that is designated for nursery operations. As nursery operations cultivate potted plants, these operations are more suited to the varying slopes and not limited by soil type.

In the 1990s, HDOA-ARMD constructed an irrigation system consisting of approximately 12,000 feet of pipe, wells, pumps and pump house, and a water tank. The pumps and wells are located near the 20-foot elevation, with the water pumped up to the water tank for storage, providing gravity flow to the farms.

Table 65
Kahuku Irrigation System
Distribution System Condition

Distribution System	**Length** (approx. feet)	**Comments**
Pipeline		
Good Condition	12,000	Constructed circa 1990
Fair Condition	0	
Poor Condition	0	

Exhibit 24. Kahuku Irrigation System - Pumps and Wells

Exhibit 25. Kahuku Irrigation System - Water Tank

Proposed Capital Improvement Projects. Based on the assessment of the system and information gathered on the condition of various components, the following proposed CIP list was developed. Table 66 presents the proposed CIP list, estimated costs (planning level) and phase for development.

- Install a SCADA system to monitor water flow.
- Miscellaneous upgrades.
- Replace the pump house structure due to corrosion.
- Investigate and repair roadway.
- Investigate and repair sinkhole.

Table 66
Kahuku Irrigation System
Proposed Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars) Short-Term
Install SCADA (ongoing)	$850,000
Miscellaneous upgrades (ongoing)	$3,000,000
Pump house renovation	$300,000
Investigate and repair roadway	$110,000
Investigate and repair sinkhole	$110,000

3.2.4 GALBRAITH LANDS IRRIGATION SYSTEM

Ownership and service area information for the Galbraith Lands Irrigation System is presented in Table 67. General information about the system is presented in Table 68.

The George Galbraith Trust (GGT) lands cover approximately 2,100 acres of agricultural land in Central O'ahu. In the past, these lands were used for pineapple production by Del Monte Fresh Produce and Dole Food Co. Del Monte Fresh Produce operations shut down in 2008, and approximately 1,200 acres of GGT lands were put up for sale. The GGT lands used by Del Monte Fresh Produce were acquired by ADC. The acquisition is part of ADC's overall agricultural development plan for the Wahiawā area.

Table 67
Galbraith Lands Irrigation System
System Ownership and Service Area

Description	Information
Owners	State of Hawai'i ADC (System Manager)
Source	Groundwater
Estimated Current Water Use (annual average)	Farms are currently being developed
Estimated Service Area	1,021 acres
Farms Served	1,000 acres (estimated)
Important Agricultural Lands	None

Therefore, the overall areas acquired by the State of Hawai'i that are being developed for diversified agriculture are shown on Map 63. The current irrigation system may not be able to service the entire area; therefore, the service area is just a subset of the entire area. The service area also includes parcels owned by the Office of Hawaiian Affairs.

The Galbraith Lands Irrigation System (GLIS) initially consisted of the former Del Monte's Well Number 5 and a distribution system of 2 to 3 miles of 12-inch water mains with risers. The GLIS originally irrigated pineapple fields. The ADC will be improving the system to meet the irrigation needs of diversified agriculture.

Table 69 presents the land use areas within the service area. The overall system maps are shown on Maps 64 to 68, as follows:

- Map 64 - Alignments and System Components;
- Map 65 - 2014-2015 Land Use;
- Map 66 - ALISH 1977;
- Map 67 - Land Capability Non-Irrigated Conditions;
- Map 68 - Land Capability Irrigated Conditions.

Table 68
Galbraith Lands Irrigation System
General System Information

Description	Information	
System Length (feet) / status	9,925 (active) 3,164 (unverified)	
Intake Source (type) Hydrologic Unit Intake Status	Well Groundwater Groundwater Wahiawā Active	
Reservoirs Capacity Status	Reservoir 1 9.2 acre-feet (estimated) Design/ Construction	Reservoir 2 30.7 acre-feet (estimated) Design/ Construction
Visual inspection undertaken	Yes	
Irrigation system condition	Fair, see Table 70	
Rehabilitation Potential	Good	
Rehabilitation Cost / CIP (five years)	$17,000,000 See Table 71	

Table 69
Galbraith Lands Irrigation System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	0.0
Other Crops	1,081.8
Grazing	0.0

Assessment of Needs. The system is currently running, and the well pump was renovated in 2013. A list of the system components and their condition is presented in Table 70. The distribution system was constructed by Del Monte, and there were no visible leaks during the condition survey. ADC plans to construct two (2) new reservoirs for agricultural uses, and a tenant will be constructing a private reservoir. The proposed ADC reservoirs are planned to have three (3) million gallons and ten (10) million gallons of storage capacity.

ADC's short-term agricultural development plan includes the acquisition of 1,200 acres of agriculture land from Dole Food Co. In addition, there is a plan to increase irrigation water supply by using water from the Wahiawā Wastewater Treatment Plant (WWTP) and Lake Wilson. As part of the plan, storage and overflow contingences will be provided. The Wahiawā WWTP effluent has a recycle rating of R1, and Lake Wilson water has a recycle rating of R2. When the discharge of recycled water is discontinued at Lake Wilson, water use will become unrestricted.

The ADC development plan envisions the growing, processing, and distribution of agricultural commodities while accommodating food safety rules and regulations related to certain crops. Its focus is to lease land to farmers that cultivate food crops. As part of the ADC development plan, ADC acquired land from Dole Food Co. and acquired the old Tamura's warehouse in Wahiawā.

Table 70
Galbraith Lands Irrigation System
Distribution System Condition

Distribution System	**Length** (feet)	**Comments**
Pipelines		
Good Condition	0	
Fair Condition	10,000	To be replaced
Poor Condition	0	

Proposed Capital Improvement Projects. Based on the assessment of the system and information gathered on the condition of various components, the following proposed CIP list was developed. Table 71 presents the proposed CIP, estimated costs (planning level), and development phase.

- Design and construct a three (3) million-gallon reservoir for water storage.

- Design and construct a ten (10) million-gallon reservoir for water storage.
- Construct new water distribution system from the reservoirs to supply water to the farms. The estimated length of the system is 10,500 linear feet.
- Construct a facility and distribution system to use recycled water from the Wahiawā WWTP.

Table 71
Galbraith Lands Irrigation System
Proposed Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)
	Short-term
Three (3) million-gallon reservoir	$1,700,000
Ten (10) million-gallon reservoir	$5,300,000
Distribution Pipeline	$10,000,000
Irrigation from Wahiawā WWTP	
Planning	To be determined
Design and construction	To be determined

3.3 HAWAIʻI COUNTY IRRIGATION SYSTEMS

The following systems were studied in Hawaiʻi County, and their locations are shown in Exhibit 26.

- Kaʻū Agribusiness Irrigation System
- Kohala Ditch
- Kehena Ditch

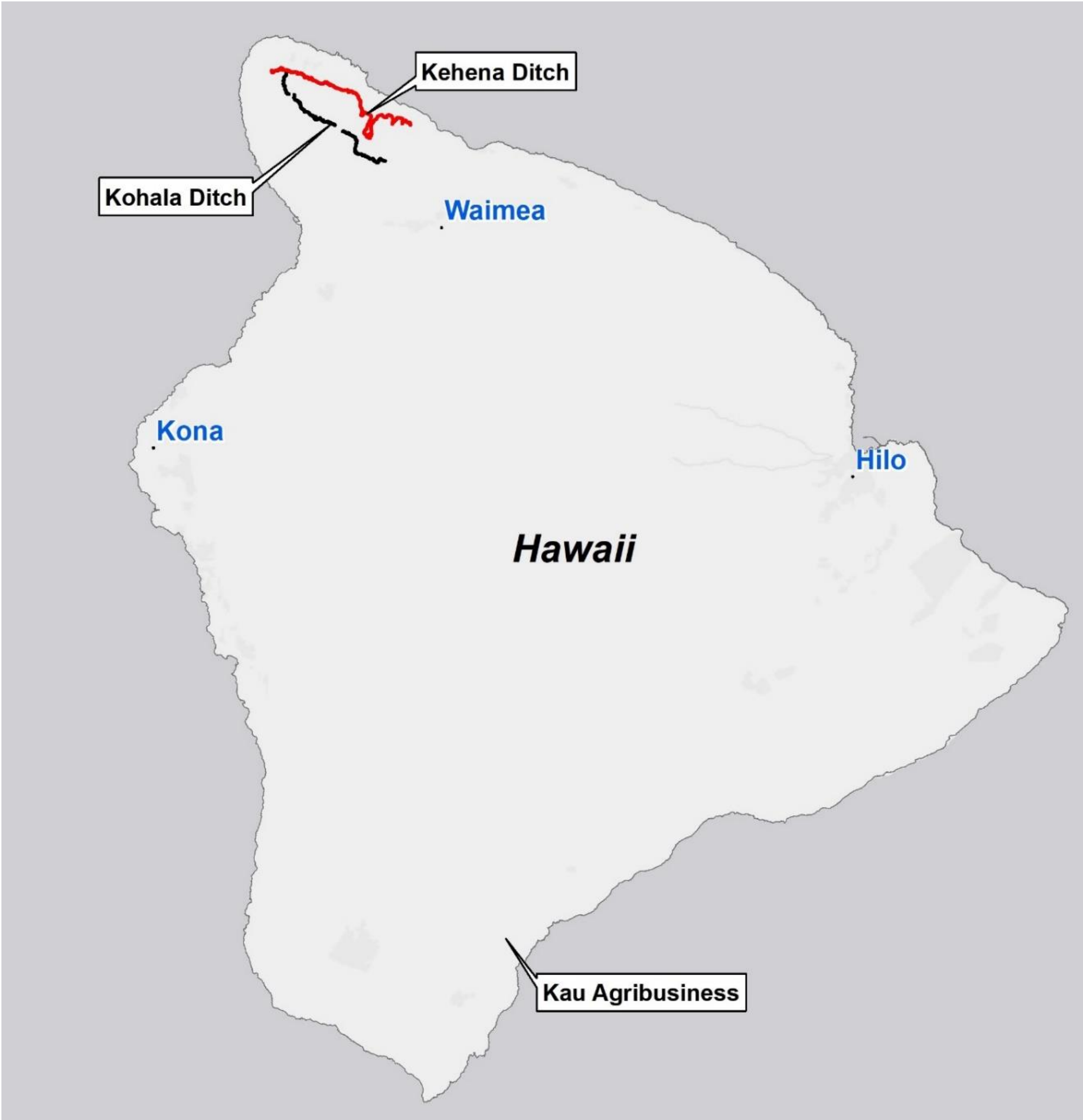

Exhibit 26. Water Systems Inventoried on Hawaiʻi

3.3.1 KAʻŪ AGRIBUSINESS IRRIGATION SYSTEM

Ownership and service area information for the Kaʻū Agribusiness Irrigation Subsystem is presented in Table 72. The Kaʻū Irrigation System was developed to support sugar production for Hawaiian Agricultural Company. By 1919, the plantation had constructed approximately 35 miles of flumes to transport sugar cane stalks to the mill. The water was suppled from 16 tunnels in mountain areas. Five (5) tunnels were constructed in the 1920s:

Kaumaikeohu, Mudflow, Noguchi, Heio, and Weda, with total length of 3,308 feet. In the 1940s, the water supply was supplemented by drilling wells. The distribution system has a total length of approximately seven (7) miles.

Table 72
Kaʻū Agribusiness Irrigation System
System Ownership and Service Area

Description	Information
Owners	Various private owners (transitioning to State of Hawaiʻi ownership)
Source	Various sources
Estimated Current Water Use (annual average)	Unverified
Estimated Service Area	71,702 acres
Farms Served	Unverified
Important Agricultural Lands	None

A total of seven (7) working water systems remain from the former plantation in the Kaʻū area. The source locations are shown on Map 69, with the approximate total extent of the service area. There are three (3) rainfall stations in the area. The Pāhala Mauka 21.3 rainfall station is at an elevation of 1,090 feet and has a mean annual rainfall of 52.44 inches. The Pāhala rainfall station is at an elevation of 875 feet and has a mean annual rainfall of 39.61 inches. The Kamāʻoa Puʻuʻeo rainfall station is at an elevation of 1,040 feet and has a mean annual rainfall of 34.52 inches.

The primary crops in the area are coffee, biofuels, cattle, and truck farming, especially in the Wood Valley area. The overall system is shown on Maps 69 to 73, as follows:

- Map 69 - Alignments and System Components;
- Map 70 - 2014-2015 Land Use;
- Map 71 - ALISH 1977;
- Map 72 - Land Capability Non-Irrigated Conditions; and
- Map 73 - Land Capability Irrigated Conditions.

Assessment of Needs. As a condition assessment was not completed, a CIP was not developed. The existing system is currently being used by various agricultural users, and ADC has not completed an assessment of needs.

3.3.2 KOHALA DITCH

Ownership and service area information for the Kohala Ditch Irrigation System is presented in Table 73. General information of the system is presented in Table 74.

The system sits in the North Kohala District of Hawai'i Island (the Big Island), from within the Kohala Mountains through Hawi, and was developed by the Kohala Ditch Company. The Kohala Ditch Company, established in 1904, was one of two (2) companies formed to supply water to sugar plantations on the northern portion of the Big Island. The other was Hāmākua Ditch Company, established around 1906, to build the Upper and Lower Hāmākua ditches.

The Kohala Ditch Company obtained a license from the Territory of Hawai'i in 1904 for a period of fifty years to "enter upon, confine, conserve, collect, impound, and divert all the running natural surface waters on the *Kohala Hāmākua Watershed*."

Table 73
Kohala Ditch System
System Ownership and Service Area

Description	Information
Owners	Kamehameha Schools Bishop Estate
Source	Various streams and springs
Estimated Current Water Use (annual average)	50 MGD (estimated)
Estimated Service Area	17,000 acres
Farms Served	Unverified
Important Agricultural Lands	None

Table 74
Kohala Ditch System
General System Information

Description	Information		
System Length (feet) / status	124,025 (unverified)		
Intakes	See Table 76		
Reservoirs (1)	Hawi No. 5	Hawi No. 3	Puakea
Capacity (acre-feet(2) / MG)	55 / 17.9	--	Unverified
Status	Active	Decommissioned	Unverified
Visual inspection undertaken	No		
Irrigation system condition	Active		
Rehabilitation Potential	Good		
Rehabilitation Cost/CIP	To be determined by owner		

NOTE: 1) Not all reservoirs are accounted for, as visual survey was not performed
2) DLNR Dam Inventory System database. http://dams.hawaii.gov

The Kohala Ditch supplied water to plantations including Union Mill, Kohala Sugar, Niuli'i Plantation, Hawi Sugar, and Hālawa Plantation. At the time, the entire ditch was about 23 miles long, with 57 tunnels traversing about 16 miles, the longest being 2,500 feet. The system has approximately six (6) miles of open ditch and 23 miles of flumes. The ditch was lined primarily with stone or cement to Hawi and unlined beyond Hawi. The tunnels are cement lined, and the flumes are seven (7) feet wide and six (6) feet deep.

The Honokāne section was opened in 1906 to provide water to the following plantations: Kohala, Niuli'i, Hālawa, Kohala, Hawi, and Union. The 'Āwini section was finished in 1907 and served Pu'ukea Plantation. On average, the ditch delivered 22 to 30 MGD.[14] The literature reports minimum flow as low as 3.5 MGD. The designed capacity was originally 70 MGD, but later reduced to 50 MGD when the original flumes were replaced with smaller ones. There is one (1) rainfall station, the Kohala Mission rainfall station, located at an elevation of 535 feet with a mean annual rainfall of 71.50 inches.

The land use areas within the service area are shown in Table 75. The overall system is shown on Maps 74 to 78, as follows:

- Map 74 - Alignments and System Components;
- Map 75 - 2014-2015 Land Use;
- Map 76 - ALISH 1977;
- Map 77 - Land Capability Non-Irrigated Conditions; and
- Map 78 - Land Capability Irrigated Conditions.

Table 75
Kohala Ditch System
Land Uses within the Service Area

Cultivation	**Area** (acres)
Field Crops	0.0
Other Crops	1,071.9
Grazing	4,823.8

[14] Wilcox, Carol, *Sugar water, Hawai'i's Plantation Ditches*, Honolulu, University of Hawai'i Press, 1996.

Table 76
Kohala Ditch System
Intake Description

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion	Hapahapai	Kohala	Unverified
Stream Diversion	Waiakauaua	Kohala	Unverified
Stream Diversion	Waiakauaua	Kohala	Unverified
Spring	Not applicable	Kohala	Unverified
Stream Diversion	Hālawa	Kohala	Unverified
Stream Diversion	Hālawa	Kohala	Unverified
Stream Diversion	Waiaohia	Kohala	Unverified
Stream Diversion	Waipuhi	Kohala	Unverified
Stream Diversion	Waipunalau	Kohala	Unverified
Stream Diversion	Pakolea	Kohala	Unverified
Stream Diversion	ʻAʻamakāō	Kohala	Unverified
Stream Diversion	Niuliʻi	Kohala	Unverified
Stream Diversion	Waikani	Kohala	Unverified
Stream Diversion	Waikani	Kohala	Unverified
Stream Diversion	Waikani	Kohala	Unverified
Stream Diversion	Niuliʻi	Kohala	Unverified
Stream Diversion	Waikani	Kohala	Unverified
Stream Diversion	Niuliʻi	Kohala	Unverified
Stream Diversion	Niuliʻi	Kohala	Unverified
Stream Diversion	Niuliʻi	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikaina	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waikama	Kohala	Unverified
Stream Diversion	Waiakalaʻe	Kohala	Unverified
Stream Diversion	Waiakalaʻe	Kohala	Unverified
Spring	Not applicable	Kohala	Unverified
Stream Diversion	Honokāne	Kohala	Unverified
Stream Diversion	Honokāne	Kohala	Unverified

Assessment of Needs. As a condition assessment was not completed, a CIP was not developed. The system is active and managed and maintained by a private owner.

3.3.3 KEHENA DITCH

Ownership and service area information for the Kehena Ditch Irrigation System is presented in Table 77. General information about the system is presented in Table 78.

Circa 1970, the County of Hawai'i planned to use Kehena Ditch as a drinking water source for the South Kohala area. This ambitious plan to transport water to the Kawaihae area was abandoned around 1974 due to the enactment of the Safe Drinking Water Act.[15] During construction, a portion of the Kehena Ditch was partially demolished and replaced by a pipeline, which is currently active. Kahua and Ponoholo Ranches have installed new pipelines from the pipeline terminus to supply water to their respective ranching operations.

Historical USGS records indicate an average daily flow of six (6) MGD, with a maximum flow of 14 MGD, and an estimated average flow during low-flow months as 4.2 MGD, rising to 9.7 MGD during high-flow months. The owners stated that there was substantial water loss in the distribution network, especially from the unlined ditch segments.

There are two (2) rainfall stations in the area: one located at the Kahua Ranch Headquarters and the other at the Middle Pen. The Kahua Ranch Headquarters station is located at an elevation of 3,269 feet, with a mean annual rainfall of 69.39 inches. The Middle Pen station is located at an elevation of 1,380 feet and has a mean annual rainfall of 15.64 inches.

[15] The Safe Drinking Water Act increased regulation on the use of surface water for drinking water.

The land use areas within the service area are presented in Table 79. The system maps are shown on Maps 79 to 83, as follows:

- Map 79 - Alignments and System Components;
- Map 80 - 2014-2015 Land Use;
- Map 81 - ALISH 1977;
- Map 82 - Land Capability Non-Irrigated Conditions; and
- Map 83 - Land Capability Irrigated Conditions.

Table 77
Kehena Ditch System
System Ownership and Service Area

Description	Information
Owners	State of Hawai'i, Kahua Ranch and Ponoholo Ranch Maintained by ranchers served by the system
Source	Various streams
Estimated Current Water Use	Less than 1 MGD (low flow estimate)
Estimated Potential Service Area	19,235 acres
Farms Served	Three (3) ranches
Important Agricultural Lands	None

Table 78
Kehena Ditch System
General System Information

Description	Information	
System Length (feet)/Status	42,566 (active) 32,011 (inactive) 1,545 (unverified)	
Intakes	Various, see Table 80	
Reservoirs	Pūnāwai	Kehena
Capacity (acre-feet / MG)	30 / 10	57 / 19
Status	Active	Decommissioned
Reservoirs	Puuokumau	Unnamed
Capacity (acre-feet / MG)	Unverified	15 / 5
Status	Decommissioned	Active
Visual inspection undertaken	Yes	
Irrigation system condition	See Tables 81 and 82	
Rehabilitation Potential	Good	
Rehabilitation Cost / CIP (five years)	$7,250,000 See Table 83	

Table 79
Kehena Ditch System
Land Uses within the Service Area

Cultivation	Area (acres)
Field Crops	0.0
Other Crops	6.7
Grazing	9,178.2

Table 80
Kehena Ditch System
Intake Description

Intake Type	Stream	Hydrologic Unit	Status
Stream Diversion	Unverified	Kohala	Unverified
Stream Diversion	Unnamed	Kohala	Unverified
Stream Diversion	Unnamed	Kohala	Unverified
Stream Diversion	Unnamed	Kohala	Unverified
Stream Diversion	Honokāne	Kohala	Active
Stream Diversion	Unnamed	Kohala	Unverified
Stream Diversion	Unnamed	Kohala	Unverified

Assessment of Needs. The visual walkthrough of the system was performed in 2015. The ranches' demand for water is increasing with consumer demand for grass-fed beef. Therefore, it is necessary to increase the acreage of grass pastures to maintain the grass-fed label for these cattle. The water required for these grass-fed pastures is supplied by both rainfall and the Kehena Ditch Irrigation System.

Parker Ranch uses the lower portion of the original Kehena Ditch, from its south boundary to Kehena Reservoir. The ranch has installed two (2) smaller water storage systems as well. The ditch section beyond Parker Ranch lands, heading north toward Hawi, is not in use and in poor condition. Exhibits 27 and 28 show representative photos of the ditch.

The Kehena system water supply is highly variable and susceptible to low rainfall conditions. During dry periods, the water flow is reduced to less than one (1) MGD. As low rainfall occurs frequently, additional water storage is required, and other water sources should be developed. The distribution system components and their conditions are presented in Tables 81 and 82.

Exhibit 27. Kehena Ditch Irrigation System

Exhibit 28. Kehena Ditch Irrigation System -
Ditch (left) & Flow Structure (right)

Table 81
Kehena Ditch System
Distribution System Components

Distribution System	**Length** (feet)
Ditches	
Active	37,566
Inactive	32,820
Tunnels	
Active	10,526
Inactive	737
Flumes	
Active	114
Inactive	0
Pipelines	
Active	152
Inactive	0

Table 82
Kehena Ditch System
Distribution System Condition
(Active Components Only)

Distribution System	**Length** (feet)
Ditches	
Good Condition	37,326
Fair Condition	225
Poor Condition	15
Tunnels	
Good Condition	10,526
Fair Condition	0
Poor Condition	0
Flumes	
Good Condition	0
Fair Condition	0
Poor Condition	114
Pipelines	
Good Condition	152
Fair Condition	0
Poor Condition	0

Proposed Capital Improvement Projects. As grass-fed beef demand is increasing, there is a need to provide more irrigated pasture lands. The amount of water required for growing irrigated pastures is estimated to be approximately 9,000 gpd/acre but will vary due to soil conditions, wind, etc. To accommodate this growth, there is a need for additional water sources, as well as additional storage (reservoir) capacity. Other landowners in the Kohala and Kawaihae areas would benefit from the development of additional water systems for agricultural use.

The condition survey found certain portions of the distribution and collection system in need of significant repair. The higher elevation intakes were not accessible at the time, but they could provide additional water when operating properly. The following is a list of proposed improvements and project phasing. There are two phases: 1) to improve water supply to current users; and 2) to expand the user base. Based on the assessment of the system and information gathered on the condition of various components, the following proposed CIP list was developed (see Table 83). In addition, the ditch and catwalks should be renovated.

- Short-term (1-5 years)
    - Complete miscellaneous repairs of the flume, catwalks, etc.
    - Plan for additional water storage and complete preliminary design. Compliance with the regulatory process will be required.
    - Complete design of additional water sources and water storage, with construction to follow.

Table 83
Kehena Ditch System
Proposed Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)
	Short-term
Ditch, tunnel, trail, and catwalk renovation and maintenance; flume renovation and other miscellaneous improvements	$200,000
Develop additional water storage and intakes	
Planning and design	$6,600,000
Construction	To be determined
Develop additional water sources for Kehena users and surrounding landowners	
Planning	$450,000
Design and construction	To be determined

CHAPTER 4
UPDATE OF 2004 IRRIGATION SYSTEMS

Nobody is qualified to become a statesman who is entirely ignorant of the problem of wheat.

Socrates

The 2004 AWUDP studied 13 irrigation systems, including both public and private water systems. This study aims to update system component information; provide maps of system components, land use, and soil characteristics; identify IAL in the service area; provide the status of the 2004 CIP; and present the current CIP.

A summary of CIP from 2004 to 2014 for the irrigation systems studied in 2004 is presented in Table 84. The systems studied in the 2004 AWUDP are listed below and shown in Exhibit 29.

Kaua'i County

- East Kaua'i Irrigation System
- Kekaha Ditch Irrigation System
- Kōke'e Ditch Irrigation System
- Kaua'i Coffee Irrigation System

Maui County

- Maui Land and Pineapple/Pioneer Mill Irrigation System
- East Maui Irrigation System
- West Maui Irrigation System
- Upcountry Maui Irrigation System
- Moloka'i Irrigation System

O'ahu (City and County of Honolulu)

- Waiāhole Ditch Irrigation System
- Waimānalo Irrigation System

Hawai'i County

- Lower Hāmākua Ditch Irrigation System
- Waimea Irrigation System

Table 84
Summary of 2004 Capital Improvement Program

Irrigation System	Manager/ Owner	2004 CIP (000s)	Estimated Service Area (100 acres)		Cultivated Area (100 ac.)**	Grazing Area (100 ac.)**
				ALISH		
KAUA'I						
East Kaua'i	East Kaua'i Water Users' Cooperative/ADC	$10,387	59.2*	55.1*	15.3	43.8
Kaua'i Coffee	McBryde Company (A&B)	n/a	46.6*	43.7*	39.0	4.9
Kekaha Ditch	Kekaha Agriculture Association/ADC	$6,790	65.7*	64.5*	65.2	--
Kōke'e Ditch	Kekaha Agriculture Association/ADC	$1,712	--	--	--	--
O'AHU						
Waiāhole Ditch	ADC	$10,668	62.7*	57.3*	40.0	--
Waimānalo	HDOA	$5,492	15.8*	15.2*	8.1	1.1
MAUI						
Moloka'i	HDOA	$16,776	98.9*	77.8*	26.7	6.8
Upcountry Maui	HDOA	$9,274	17.2*	10.3*	4.0	2.5
East Maui	East Maui Irrigation Co. Ltd.	n/a	--	--	--	--
West Maui	Wailuku Agribusiness Co/Alexander & Baldwin	n/a	64.3*	63.0*	63.2	--
Maui Land and Pineapple/Pioneer Mill	Maui Land and Pineapple	$8,912	--	--	---	--
HAWAI'I						
Lower Hāmākua Ditch	HDOA	$9,586	46.6*	39.5*	3.1	36.7
Waimea	HDOA	$20,963	19.9	12.4*	7.4	5.7

Note: * HDOA-ARMD, *"Agricultural Water Use and Development Plan,"* 2004.
** data from HDOA-ARMD, Geographical Information System.

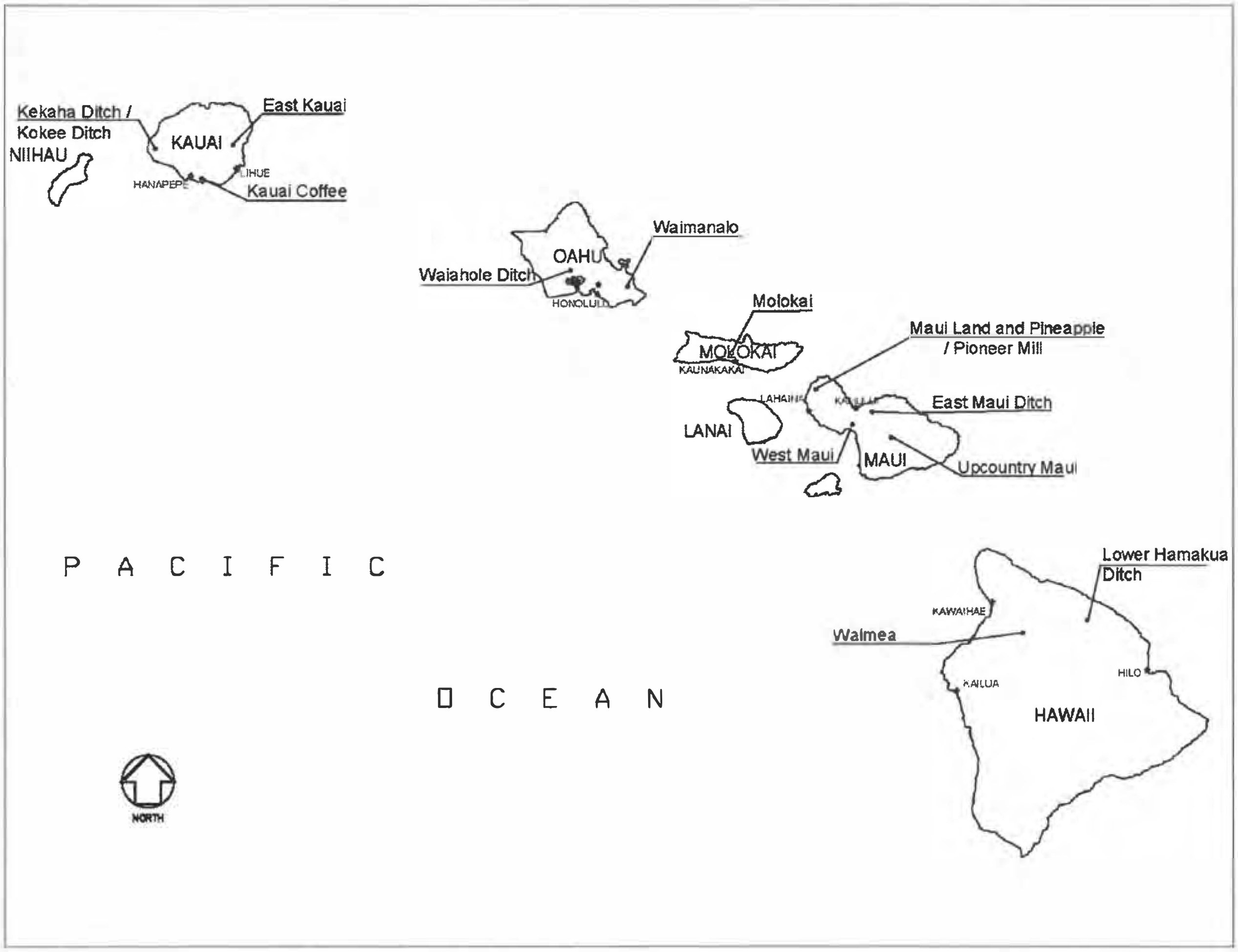

Exhibit 29. Agricultural Water Systems Studied in the 2004 AWUDP

The sections of this Chapter are organized to present the water irrigation systems by management agencies. Therefore, Section 4.1 updates the water systems owned and managed by HDOA-ARMD, Section 4.2 updates the water systems managed by or in partnership with ADC, and Section 4.3 updates the water systems owned and managed by private entities.

The base maps of the irrigation system maps are derived from information provided by HDOA (circa 2007):

- Alignments and System Components;
- Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- ALISH 1977;

- Land Capability Non-Irrigated Conditions;
- Land Capability Irrigated Conditions; and
- IAL, if appropriate.

4.1 HAWAIʻI DEPARTMENT OF AGRICULTURE SYSTEMS

The following HDOA-ARMD systems were inventoried in the 2004 AWUDP and have been updated based on discussions with HDOA-ARMD.

- Waimānalo Irrigation System, Oʻahu.
- Molokaʻi Irrigation System, Molokaʻi.
- Upcountry Maui Irrigation System, Maui.
- Waimea Irrigation System, Hawaiʻi.
- Lower Hāmākua Ditch, Hawaiʻi.

4.1.1 WAIMĀNALO IRRIGATION SYSTEM

The Waimānalo Irrigation System (WIS) has a service area of 1,174 acres[16] and is in the Waimānalo sub-aquifer of the Windward aquifer. In 2003, the system served 60 acres. The system intakes water from Maunawili, ʻAinoni and Makawao streams. The USGS gage station that measures source intake is no longer operational.

The system has undergone significant changes since 2004. The system is still fed by the existing Waimānalo ditch, but it has a new storage system, pipeline, and metered distribution network for its customers. The old reservoirs were decommissioned, and a new 60 MG (184 acre-feet) reservoir was constructed above (mauka) the Waimānalo agricultural area.

There are three (3) rainfall stations in the area: the Maunawili station, which is near the source, and two stations within the Waimānalo farm area. The Maunawili station is at an elevation of 417 feet, with a mean annual rainfall of 73.18 inches. The first station within the farm area is Waimānalo Experiment station, at an elevation of 60 feet, with a mean annual rainfall of 42.10 inches.

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[16] Hawaiʻi Department of Agriculture, Agricultural Resource Management Division, Irrigations Systems website, April 29, 2015, http://hdoa.hawaii.gov/arm/irrigation-systems/.

The second is the Waimānalo Nonokio station, located at an elevation of 66 feet, with a mean annual rainfall of 44.94 inches.

The irrigation system is approximately 15 miles long and transports 150.0 million gallons per year. The forecast average water demand is estimated to be 5.3 MGD. The system maps are shown on Maps 84 to 88, as follows:

- Map 84 - Alignments and System Components;
- Map 85 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 86 - ALISH 1977;
- Map 87 - Land Capability Non-Irrigated Conditions; and
- Map 88 - Land Capability Irrigated Conditions.

Table 85 presents the status of the CIP program that was developed in the 2004 AWUDP. Table 86 provides a list of CIP projects performed from 2004 to 2014 and their status.

TABLE 85
Waimānalo Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvements	Status
1	Land	Land treatment	Deferred
2	Maunawili source	Improve water collection system	Completed
3	Reservoir	Install irrigation pipeline system	Completed
4	Ditch	Install irrigation pipeline system	Completed
5	Ditch	Modify old irrigation ditch	Ongoing
6	Sewage	Construct sewage effluent pumps, pipeline system, and storage reservoir	Deferred
7	Waste management	Install solid waste collection sites	Deferred
8	Reservoirs	Restore three (3) abandoned reservoirs (reservoirs are not in use or decommissioned)	Deleted

Note: Deferred project – Past project recommendation. Reevaluation required for applicability, necessity, and feasibility. Defer to new CIP projects.

Table 86
Waimānalo Irrigation System
2004-2014 Capital Improvement Projects

No.	Item	Improvements	Status
1	Land	DLNR land transfer	Ongoing
2	Distribution	Pipeline stabilization	Completed
3	Distribution	Extend pipeline (Wong Ditch)	Completed
4	Safety	Miscellaneous safety improvements	Completed
5	Baseyard	Renovations at HDOA baseyard	Ongoing
6	Ditch	Miscellaneous ditch repairs	Completed
7	Source	Install Emergency Pump Well No. 1	Completed

As most of the system has already been upgraded, the remaining components need to be upgraded or renovated. Therefore, the proposed CIP for the Waimānalo Irrigation System are listed below and summarized in Table 87.

- Construct a new office building, renovate baseyard, and install safety features. In addition, conduct miscellaneous improvements in the system, such as restoring access roads; renovating ditch with HDPE pipe; and repairing or replacing gates, fencing, grates, etc.

- Design a replacement pipeline for portions of remaining ditch to reduce system water losses and maintenance costs. Construction costs will be determined after design.

- Tayli Reservoir Improvements.

Table 87
Waimānalo Irrigation System
2018 Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars)	
	Phase I	Phase II
Renovation of baseyard and miscellaneous improvements	$3,500,000	
Replace remaining ditch portion with pipeline		
Design		$1,000,000
Construction		To be determined
Tayli Reservoir Improvements	$1,300,000	

4.1.2 MOLOKA'I IRRIGATION SYSTEM

The Moloka'i Irrigation System (MIS) is in the Waikolu sub-aquifer of the Northeast aquifer. The Moloka'i Irrigation System services lands in the Manawainui, Hoolehua and Kualapu'u sub-aquifers of the Moloka'i Central aquifer. The system intakes water from Waikolu Stream and has one of the largest reservoirs (Kualapu'u Reservoir) in the state, with a storage capacity of 1,656.0 million gallons (5,082 acre-feet). The system serves agricultural lands and the Department of Hawaiian Home Lands.

There are no active rainfall stations in the farming areas. The closest is the Waikolu rainfall station, located in the mountains at an elevation of 3,550 feet. This station has a mean annual rainfall of 102.64 inches. There is also an inactive rainfall station (Field 305) near Kualapu'u Reservoir, at an elevation of 875 feet, with a mean annual rainfall of 27.92 inches (data collected between 1948-1983).

The service area for MIS is approximately 9,730 acres. The system is 25 miles long and transports 1.2 billion gallons per year. The forecast average water demand is estimated to be 11.2 MGD. The system maps are shown on Maps 89 to 93, as follows:

- Map 89 - Alignments and System Components;
- Map 90 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al);
- Map 91 - ALISH 1977;
- Map 92 - Land Capability Non-Irrigated Conditions; and
- Map 93 - Land Capability Irrigated Conditions.

Table 88 presents the status of the CIP program that was developed in the 2004 AWUDP. Table 89 provides a list of CIP projects performed from 2004 to 2014 and their status. The proposed CIP for the Moloka'i Irrigation System is summarized in Table 90.

Table 88
Moloka'i Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvements	Status
1	Kawela Stream Diversion	Raise existing diversion dam height by two (2) feet	Deferred
2	Activated Unused Well	• Install new well casing • Tap into and extend power line to well site • Install submersible turbine pump and motor • Construct inlet and junction boxes • Install connecting pipeline from well to transmission pipeline	Deferred
3	Waihānau Stream Diversion	• Install new telemetry system • Construct new inlet box • Install pipeline with junction box to connect onto existing pipeline	Deferred
4	Telemetry System	• Install new telemetry system • Connect all system's facilities to central control station at office building • Install instruments, computer programs, and appurtenant works • Connect to power sources or install portable power sources	Ongoing

Note: Deferred project – Past project recommendation. Reevaluation required for applicability, necessity, and feasibility. Defer to new CIP projects.

Table 89
Moloka'i Irrigation System
2004-2014 Capital Improvement Projects

No.	Item	Improvements	Status
1	Distribution	Planning for reservoir improvements	Ongoing
2	Distribution	Installation of hydroelectric system	Deferred
3	Distribution	Concrete flume repair	Ongoing
4	Safety	Miscellaneous safety improvements	Ongoing
5	Baseyard	Renovations at HDOA baseyard	Ongoing
6	Ditch	Miscellaneous ditch repairs	Completed
7	Source	Install Emergency Pump Well No. 1	Completed

Table 90
Moloka'i Irrigation System
2018 Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars)
	Phase I
Baseyard renovation and miscellaneous improvements, Waikolu safety, Waikolu cable, irrigation system, safety assessment, miscellaneous improvements, and SCADA	$5,400,000
Dam improvements to access bridge, walkway, East Portal, and grate	$3,760,000

4.1.3 UPCOUNTRY MAUI IRRIGATION SYSTEM

The Upcountry Maui Irrigation System has a potential service area of approximately 1,500 acres in the Maui Central aquifer. Only portions of the system have been constructed, and a water source has not been secured. The system will eventually serve the agricultural lands in the Upper Kula area and Department of Hawaiian Home Lands Kēōkea area.

There are two (2) rainfall stations in the area: the Olinda rainfall station, at an elevation of 4,125 feet; and the Kula Experiment Station, at an elevation of 3,050 feet. The Olinda rainfall data has a mean annual rainfall of 66.95 inches, and the Kula Experiment Station has a mean annual rainfall of 24.43 inches.

The service area and alignment for the Upcountry Maui Irrigation System were mapped in 2007 for HDOA-ARMD. The forecast average water demand is estimated to be 3.6 MGD. The system maps are shown on Maps 94 to 98 as follows:

- Map 94 - Alignments and System Components;
- Map 95 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 96 - ALISH 1977;
- Map 97 - Land Capability Non-Irrigated Conditions; and
- Map 98 - Land Capability Irrigated Conditions.

Table 91 presents the status of the CIP program that was developed in the 2004 AWUDP. Although most of the projects are listed as ongoing, various portions of each project have been completed[17], as shown in Table 92.

[17] Communication with West Maui Soil & Water Conservation District, February 21, 2014.

Table 91
Upcountry Maui Irrigation System
2004 Capital Improvement Projects

No.	Improvements	Status
1	Main Pipeline • 0+00 to 165+00 • 165+00 to 257+00 • 257+00 to 286+00 • 286+00 to 323+00 • 323+00 to 387+00 • 387+00 to 495+00	Deleted
2	Lateral/Sublateral Pipeline • Olinda Road • Kimo Road • Crater Road • Pulehuiki/Kamehameiki • Kealahou • Waiakoa • Ka‘ono‘ulu • Waiohuli • Kēōkea/DHHL	Deleted
3	Gulch Crossing	Deleted
4	Access Road	Deleted

Table 92
Upcountry Maui Irrigation System
2004-2014 Capital Improvement Projects

Item	Improvements	Status
Distribution	Phases 1 to 5	Completed
Distribution	Phase 6A	Deferred
Distribution	Phase 6B and 1C	Deleted
Distribution	Phase 7	Deleted

4.1.4 WAIMEA IRRIGATION SYSTEM

The Waimea Irrigation System (WIS) has a service area of 1,985 acres and is in the Waimanu sub-aquifer of the Kohala aquifer. This system is also known as the Upper Hāmākua Ditch (UHD). The system intakes water from Kawainui, Kawaiki, Alakahi, Waimā, and Ko'iawe streams. The system serves agricultural lands in the Lālāmilo area and Department of Hawaiian Home Lands in the Pu'u Kapu, and Waimea areas. The rainfall in Lālāmilo Farm Lots is measured at Lālāmilo Field Office station, at an elevation of 2,620 feet, with a mean annual rainfall of 19.85 inches.

The length of the system is 15 miles, and it transports approximately 307.2 million gallons per year. The forecast average water demand is estimated to be 10.0 MGD. The system maps are shown on Maps 99 to 103, as follows:

- Map 99 - Alignments and System Components;
- Map 100 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 101 - ALISH 1977;
- Map 102 - Land Capability Non-Irrigated Conditions; and
- Map 103 - Land Capability Irrigated Conditions.

Table 93 presents the status of the CIP program that was developed in the 2004 AWUDP. Table 94 provides a listing of other CIP projects performed from 2004 to 2014 and their status. The proposed CIP for the Waimea Irrigation System is summarized in Table 95.

Table 93
Waimea Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvements	Status
1	UHD Improvements	• UHD bypass pipelines • UHD to Waimea II reservoir supply pipeline	Deferred
2	Waimea II Reservoir	• Construct lined reservoir	Deferred
3	Irrigation Water Distribution System	• Lālāmilo Addition • DHHL additions • Waimea II to existing mainline	Deferred
4	Livestock Water Distribution System	• Main, Group 2, E, E-1 • Group 1 • Group 3 • Group 5 • Group 7 • Group 9	Deferred
5	Pumps	• Convert two (2) electrical pumps to diesel	Deferred
6	Telemetry System	• Install new system to control & monitor flows	Deferred

Note: Deferred project – Past project recommendation. Reevaluation required for applicability, necessity, and feasibility. Defer to new CIP projects.

Table 94
Waimea Irrigation System
2004-2014 Capital Improvement Projects

No.	Item	Improvements	Status
1	Reservoir	Dam safety improvements - Puʻu Pelehu and Puʻu Kapu	Design completed
2	Ditch	Open ditch improvements (earthquake)	Completed
3	Ditch	Alakahi	Deferred
4	Distribution	Lālāmilo Distribution Pipeline	Completed
5	Baseyard	Renovate HDOA baseyard	Pending
6	Distribution	Flume replacement	Completed
7	DHHL	Agriculture subdivision water distribution	Completed
8	Source	Koʻiawe intake design and construction	Ongoing
9	System	Hydropower plant	Canceled

Table 95
Waimea Irrigation System
2018 Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)	
	Phase I	**Phase II**
Miscellaneous improvements: • Koʻiawe Intake – install blow-off valve and slide gate • Upper Ditch lining repair (approx. 100 LF) • Waimā Intake – diversion wall repair • Kawaiki slide gate repair • Tunnel lining repair	$1,100,000	
Retrofit system with pipeline		
Design		To be determined
Construction		To be determined
Puʻu Kapu Reservoir Safety Improvements - Construction	$ 5,600,000**	

** Combined construction cost with Pauuilo Reservoir (Lower Hāmākua Ditch System)

4.1.5 LOWER HĀMĀKUA DITCH

The Lower Hāmākua Ditch (LHD) has a service area of 4,214 acres and is in the Waimanu sub-aquifer of the Kohala aquifer. The system intakes water from Kawainui, Alakahi, Koʻiawe, and Waimā streams, and has a length of approximately 26 miles. The rainfall station within the Honokaʻa-Paauilo area is the Honokaʻa Town station, at an elevation of 1,070 feet, with a mean annual rainfall of 89.99 inches. The forecast average water demand is estimated to be 12.5 MGD. The system maps are shown on Maps 104 to 108, as follows:

- Map 104 - Alignments and System Components;
- Map 105 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 106 - ALISH within 1977;
- Map 107 - Land Capability Non-Irrigated Conditions; and
- Map 108 - Land Capability Irrigated Conditions.

Table 96 presents the status of the CIP developed in the 2004 AWUDP. Table 97 provides a listing of other CIP performed from 2004 to 2014 and their status. The proposed CIP for the Lower Hāmākua Irrigation System is summarized in Table 98.

Table 96
Lower Hāmākua Ditch System
2004 Capital Improvement Projects

No.	Item	Improvements	Status
1	Land	Conservation assistance	Deferred
2	Land	Technical assistance	Deferred
3	Land	Waipiʻo Valley assistance	Deferred
4	Ditch	Repair flume	Ongoing
5	Ditch	Remove sediment	Ongoing
6	Ditch	Repair concrete lining	Ongoing
7	Intake	Modify intakes	Completed
8	System	Install lateral system	Deferred
9	Ditch	Install exclusion fencing	Ongoing
10	Intake	Install SCADA system	Deferred
11	Intake	Reactivate Waimā Intake	Deferred

Note: Deferred projects are being reevaluated for applicability and cost, and for compliance with current policies, rules, and regulations.

Table 97
Lower Hāmākua Ditch System
2004-2014 Capital Improvement Projects

Item	Improvements	Status
Dam/ Reservoir	Pauuilo dam and reservoir safety improvements	Construction ongoing
Source	Alakahi Intake reconstruction	Completed
Distribution	Replace old plantation irrigation system	Ongoing
System	Miscellaneous system improvements	Construction ongoing
Baseyard	HDOA Baseyard renovation (see Waimea)	Pending
Source	Ko'iawe reconstruction	Pending
Source	Alakahi reconstruction	Completed
Distribution	Ditch lining stabilization and repair – Phase I	Completed

Table 98
Lower Hāmākua Ditch System
2018 Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars)	
	Phase I	Phase II
Baseyard renovation and miscellaneous improvements (see Waimea)	To be determined	
Ditch lining stabilization and repairing – Phase II		$1,100,000
Agricultural Park meters	$275,000	
Exclusion fencing	$275,000	
Retrofit with pipeline		
Design		$1,400,000
Construction		To be determined
Pauuilo Reservoir Safety Improvements	$5,600,000**	

** Combined construction cost with Pu'u Kapu Reservoir (Waimea Irrigation System)

4.2 HAWAI'I AGRIBUSINESS DEVELOPMENT CORPORATION / PARTNERSHIP SYSTEMS

The following systems were described in the 2004 AWUDP and are managed by ADC or in partnership with private organizations:

- Kekaha Ditch Irrigation System, Kaua'i;
- Kōke'e Ditch Irrigation System, Kaua'i;
- East Kaua'i Irrigation System, Kaua'i; and
- Waiāhole Ditch Irrigation System, O'ahu.

4.2.1 KEKAHA DITCH IRRIGATION SYSTEM

The Kekaha Ditch Irrigation System (KEDIS) services approximately 6,570 acres of agricultural land. The water source for KEDIS is the Kekaha sub-aquifer in the Waimea aquifer. The system intakes water from Waimea River. There is a gage on the KEDIS system; flow data is summarized in Table 99. The overall mean flow at Kekaha Ditch gauge is 29.3 MGD, with minimum flow of 0.0 MGD and maximum flow of 49.4 MGD. Historical data from USGS showed a gauge at Camp 1 had an average flow of 33.6 MGD during low-flow months and an average flow of 40.7 MGD during high-flow months.

There are no active rainfall stations in the area. However, the Niu Ridge Station, at an elevation of 1,250 feet, was operational until 2000. Data shows a mean annual rainfall of 26.09 inches.

The KEDIS system maps are shown on Maps 109 to 113, as follows:

- Map 109 - Alignments and System Components;
- Map 110 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 111 - ALISH 1977;
- Map 112 - Land Capability Non-Irrigated Conditions; and
- Map 113 - Land Capability Irrigated Conditions

Table 99
Kekaha Ditch Irrigation System
Reported Flows

Gage Location	**Reported Monthly Average Flows at Gage Locations [1] (MGD)**											
	2012 (11 months)		**2013**		**2014**		**2015**		**2016**		**2017** (7 months)	
	low	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**	**high**
Waimea Hydro	14.1	40.8	14.8	26.7	13.0	24.1	0.0	45.7	12.0	15.0	10.3	13.6

1) Data reports are from Commission on Water Resource Management and could contain estimates and incomplete records. The exact location of measurements may not be reported.

Since the 2004 AWUDP, the KEDIS has not undergone any major modifications to the system or alignment, other than those improvements identified in the 2004 CIP. The status of the 2004 CIP is shown in Table 100, and the projects which were completed from 2004 to 2014 are shown in Table 101. The proposed CIP for the Kekaha Ditch Irrigation System is summarized in Table 102. One of the ongoing projects for this system is the renovation of the 14 reservoirs between Waiwa and Polihale. This project is expected to take approximately three (3) years, with a cost between $5 million to $8 million.

In 2013, there was a petition filed to amend the instream flow standards for Waimea River, and in 2017, CWRM approved the terms of the settlement. Pursuant to the settlement, KEDIS can only receive diverted water after instream flows are met at the various Waimea River diversions. The development of the system will be reassessed due to this settlement.

Table 100
Kekaha Ditch Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvements	Status (2014)
1	Waipao Gulch Pipe Crossing	Demolish pipe; install pipe supports and 42-inch HDPE siphons	Completed
2	Equipment Access Road(s)	Clear and grub, install pavement (1,000 foot)	Completed
3	Koaiʻe Stream Intake	Install automatic bar screen/cleaner and control gate; install power source, equipment shelter, and concrete apron	Completed
4	Waihuiu Stream Intake	Install automatic bar screen/cleaner and control gate; install power source, equipment shelter, and concrete apron	Completed
5	Black Pipe Siphon Inlet	Install Concrete Rock Masonry (CRM) lining and 20-LF 26 in. HDPE slip-lining; replace intake	Completed
6	Various Control Gate	Retrofit control gates with new valves and channel structures; add metering; redesign flow controls at Waimea forebay tunnel, Waimea Heights-Menehune Ditch lateral, Pali flumes, Obake bridge, and Menehune Ditch junction box	Completed
7	Pali Flume	Replace two sections of Pali flumes (80-120 feet) with bypass tunnel	Completed
8	Reservoirs	Clean, grade, and install HDPE lining on 14 reservoirs between Waiwa and Polihale	In progress.

Table 101
Kekaha Ditch Irrigation System
2004-2014 Capital Improvement Projects

Item	Improvements	Status (2014)
Maintenance	Damages to system and roadways due to heavy rainfall events	Completed
Distribution	Halemanu stave pipe replaced with HDPE pipeline	Completed
Distribution	Black Pipe Siphon Inlet renovated	Completed
Distribution	Control gates, various improvements	Completed
System	Phase 6B and 1C security gates were installed at the main entrances	Completed

Table 102
Kekaha Ditch Irrigation System
2018 Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars)
	Phase I
System Maintenance	$11,000,000

4.2.2 KŌKE'E DITCH IRRIGATION SYSTEM

The Kōke'e Ditch Irrigation System (KODIS) has an intake below Alaka'i Swamp and other intakes on Waiakoali, Kawaikōī, Kauaikinana and Kōke'e streams, which lie in the Kekaha sub-aquifer of the Waimea aquifer. There is a gage on the KODIS system, and flow data is summarized in Table 103. The overall mean flow at the Kōke'e Ditch-Pu'ulua reservoir gage is 12.4 MGD, with a minimum flow of 0.0 MGD and a maximum flow of 36.7 MGD.

Historical data from USGS shows that a gage near Waimea has an estimated average flow of 8.4 MGD during low-flow months and 22.6 MGD during high-flow months. There are no active rainfall stations in the area, but the Puehu Ridge station has records until 2000. The station is at an elevation of 1,660 feet, and data shows a mean annual rainfall of 27.71 inches.

Since the 2004 AWUDP, there were no major changes to the alignment or components of the system. However, due to the 2017 settlement with CWRM for Kekaha Ditch, the development of the system needs to be reassessed. Like Kekaha Ditch, normal maintenance will be ongoing. The 2004 CIP and the current (2014) status is shown in Table 104.

Table 103
Kōke'e Ditch Irrigation System
Reported Flows

Gage Location	Reported Monthly Average Flows at Gage Locations [1] (MGD)											
	2012 (11 months)		2013		2014		2015		2016		2017 (7 months)	
	low	high	low	high	low	high	low	high	low	high	low	high
Pu'ulua Reservoir	0.0	10.0	1.0	9.0	1.0	2.0	1.0	3.0	2.0	2.0	1.0	2.0

1) Reports are from Commission on Water Resource Management and could contain estimates and incomplete records. The exact location of measurements may not be reported.

Table 104
Kōke'e Ditch Irrigation System
2004 Capital Improvement Projects

No	Item	Improvements	Status (2014)
1	Kawaikōī Flume	Demolish flume; install wooden trestle, 48-inch semi-circular corrugated metal pipe (CMP), HDPE lining; conduct structural study	Completed
2	Pu'u Lua Reservoir	Site work; install HDPE lining on dam, pipe burst/24-inches HDPE, discharge pipe; install 24-inch globe valve, flow meter, and appurtenances	In progress with DLNR
3	Pu'u Moe Ditch Divide	Site work; install new divide, Parshall flumes, flow meters, and appurtenances	Pending due to settlement

4.2.3 EAST KAUA'I IRRIGATION SYSTEM

The East Kaua'i Irrigation System (EKIS) services approximately 5,920 acres of agricultural lands. The water source for the EKIS is the Wailua sub-aquifer of the Līhu'e aquifer.

Historical USGS records for water flow in the system are shown on Table 105. The Kapahi rainfall station has an elevation of 520 feet, with a mean annual rainfall of 89.06 inches. The system maps are shown on Maps 114 to 118, as follows:

- Map 114 - Alignments and System Components;
- Map 115 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 116 - ALISH 1977;
- Map 117 - Land Capability Non-Irrigated Conditions; and
- Map 118 - Land Capability Irrigated Conditions.

Table 105
East Kaua'i Irrigation System
Historical Flow Data

Gage Location	**Estimated Mean Monthly Discharge** (Low) (MGD)	**Estimated Mean Monthly Discharge** (High) (MGD)
Hanamalu	9.7	23.9
Stable Storm	2.6	9.0
Kapani	2.9	5.4
Makaleha	2.1	5.4
Wailua	6.0	14.2
'A'ahoaka	0.6	1.1

The EKIS has undergone significant changes since the 2004 AWUDP, especially in water storage capacity reduction. Since 2004, the following changes to storage capacity have occurred:

- The Wailua Reservoir has been reduced in volume to meet new dam safety regulations;
- In 2013, the Hanamā'ulu Reservoir 21 storage capacity was reduced to have the reservoir deregulated; and
- The storage capacity of the Lower 'A'ahoaka Reservoir has been impaired by invasive species encroachment.

In addition, although not within EKIS, the Lower Kapahi Reservoir has been decommissioned, and the Twin Reservoirs are slated to be decommissioned. The status of the CIP listed in the 2004 AWUDP is presented in Table 106.

Table 106
East Kaua'i Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvement	Status (2014)
1	Lateral 8	Demolish 100 linear feet (LF) of 30-inch CMP; install 100 LF of new 30-inch CMP; improve ditch bank; and repair lateral eight (8) siphon inlet	Completed
2	Hanamā'ulu Flume	Demolish wooden flume and salvage; excavate unclassified backfill and buried wooden trestle; backfill earthen ditch; install new reinforced concrete flume; install concrete flume	Completed
3	Twin Reservoirs	Demolish catwalks; install new wooden catwalks and concrete platform; creosote treatment for lumber; install new control gates	Reservoir to be decommissioned
4	Upper Kapahi Reservoir	Demolish catwalk; install new wooden catwalk and concrete platform; creosote treatment for lumber; install new control gate	Completed
5	Wailua Reservoir	Demolish catwalk; install new wooden catwalk and concrete platform; creosote treatment for lumber; install new control gate; retrofit intake gate structure to main transmission line	Completed(1)
6	Hanamā'ulu Reservoir 21	Install new control valve	Completed
7	Control Gates	Retrofit approximately 15 control, bypass, and release gates	Pending
8	Diversion Works	Renovate diversion works and inlet gates for intakes on Kapa'a Stream, Wailua Ditch, Stable Storm Ditch, Hanamā'ulu Ditch	Kapa'a and Wailua completed. Hanamā'ulu not completed
9	Stable Storm Ditch	Re-route portion of Stable Storm Ditch onto state land with pipeline; construct lined reservoir	Long-term project

Note: 1) The Wailua reservoir capacity has been reduced due to compliance issues.

A notable project in the EKIS service area (circa 2015) is the harvesting of "wild" albizia trees by the biofuel company Green Energy of Kaua'i. The energy company plans to start power production with Albizia chips while the approved forestry trees for long-term biofuel needs are planted and reaching maturity.

The improvements to the 'A'ahoaka Reservoir have been completed since 2004. EKIS is another century-old system that requires repair, renovation, and upgrading to sustain or increase water flow. EKIS currently supplies water to the existing users and has potential to expand the number of acres cultivated. To provide for the potential increase in agriculture, a greater water supply must be coupled with long-term stable water flow to the agricultural lands. Therefore, EKIS has proposed the following projects to maintain existing water flow and increase it for an additional 300-plus acres. A summary of the proposed CIP is presented in Table 107.

- Overall System
    - Renovation/retrofit of control gates at various locations.
    - Planning and design to rebuild Kapahi diversion and intake structure.
    - Renovation of the Kapahi diversion and intake structure.
    - Planning and design for renovation and rebuilding of diversions at various locations.
    - Renovation of diversions at various locations.
    - Planning, design, and construction to renovate and replace control gates at various locations.
    - Reconnaissance survey to provide bathymetry data and storage capacity in reservoirs.

- Kapa'a Section
    - The access road for the main transmission line, Wailua Ditch to North Fork, needs to renovate approximately two (2) miles with 50-foot roadways, including swales and shoulders. Vegetation needs to be cleared on either side of the roadway, approximately 25 feet deep, to prevent incursion, remove blockage from falling trees and branches, and allow the road to dry after rainfall.
    - Flume 2 needs to be replaced.
    - The access road for the main transmission line (to North Fork) requires clearing and reconstruction for about one (1) mile. The access road dimensions are the same as the above.
    - The control gates on the North Fork, catwalk, and weir need to be rebuilt.
- Kālepa Section
    - Lower and Upper 'A'ahoaka Reservoirs require significant invasive species removal, typically the overgrowth of eucalyptus (paper bark) and hau.
- Lateral 8B (off from Wainaau Road) has root intrusion through the ditch walls, as well as into the tunnel. The ditch measures four (4) feet wide by five (5) feet high, and approximately 80 feet of ditch requires repair. The root intrusion into Tunnel 2 is about 80 feet into the tunnel. Tunnel 2 is approximately 200 feet long.
- Stable Storm. Planning and design for reconstruction of the intake and for replacement and rerouting of distribution line onto state land. The intake will provide a backup for the existing water demand and a long-term supply for the future increase in cultivated area.
- Distribution system. A long-term project to construct a pipeline from Upper Kapahi Reservoir to Hauiki Road and lateral 9 to Upper Kapahi.

The new pipeline will improve the longevity of the system and potentially reduce repair costs.

Table 107
East Kaua'i Irrigation System
2018 Capital Improvement Projects

Project Description	**ESTIMATED COST** (2018 dollars)	
	Phase I	**Phase II**
Repair and renovate control gates and various diversions	$110,000	
Reconstruct Kapahi Diversion	$150,000	
Restore reservoir capacity		
Capacity analysis and bathymetric survey	$230,000	
Design and construction		To be determined
Kapa'a access road and flume		
Design	$2,000,000	
Construction		$10,000,000
North Fork Access Road and miscellaneous improvements	$6,500,000	
Reopen Lower 'A'ahoaka Reservoir, clearing and dredging	$10,000,000	
Kālepa Section Lateral 8B		
Planning	$120,000	
Design and construction		To be determined
Reopen Stable Storm Ditch		
Planning	$130,000	
Design and construction		To be determined
Pipeline from Upper Kapahi Reservoir to Hauiki Road		To be determined

4.2.4 WAIĀHOLE DITCH IRRIGATION SYSTEM

The Waiāhole Ditch Irrigation System (WDIS) services approximately 6,270 acres of agricultural lands. The WDIS water comes from intake tunnels which lie in the Windward aquifer. There are no active rainfall stations within the service area, but Waiāhole rainfall station is in the source area. The Waiāhole station has an elevation of 745 feet and a mean annual rainfall of 157.06 inches. Inactive rainfall stations in the service area include O'ahu Sugar Field station 240, which was operating in Mililani until 1983, with a mean annual rainfall of 31.42 inches; and the Kunia rainfall station 807, which was operating in Camp 84 until 1983, with a mean annual rainfall of 31.77 inches.

Within the Waiāhole irrigation system service area, there are approximately 2,013 acres in two (2) IAL parcels. One (1) IAL parcel is owned by Monsanto Company, and the other parcel is owned by Hartung Brothers Hawai'i, LLC. The Monsanto Company IAL totals approximately 1,550 acres and will be used for seed corn and soybean production, and cattle grazing. Anticipated water use presented in the associated IAL Petition and Decision and Order is 0.56 MGD. The Hartung Brothers Hawai'i, LLC IAL totals approximately 463 acres and will be used for seed corn and sorghum. Anticipated water use presented in the associated IAL Petition and Decision and Order is 2.158 MGD. The system maps are shown on Maps 119 to 124, as follows:

- Map 119 - Alignments and System Components;
- Map 120 - Statewide Agricultural Land Use Baseline 2015 (Melrose et al.);
- Map 121 - ALISH 1977;
- Map 122 - Land Capability Non-Irrigated Conditions;
- Map 123 - Land Capability Irrigated Conditions; and
- Map 124 – Important Agricultural Lands.

The status of the CIP listed in the 2004 AWUDP is presented in Table 108, and Table 109 shows the projects completed between 2004 and 2014.

Table 108
Waiāhole Ditch Irrigation System
2004 Capital Improvement Projects

No.	Item	Improvements	Status (2014)
1	Reservoir 155	• Remove sediment • Install lining • Repair cut stone wall • Repair overflow channel • Construct sediment trap and floating debris screen at inlet • Remove trees along embankment • General site grading	Construction
2	Reservoir 225	• Remove sediment • Install lining • Replace cut stone wall • Construct sediment trap and floating debris screen at inlet • General site grading	Construction
3	Garst Seed Co. Supply Earthen Ditch	• Seal off earthen ditch connection • Reservoir lateral • Backfill earthen ditch	Completed
4	Siphon A	• Slip line with HDPE pipe • Bypass • Headwork modification	Construction
5	Siphon B	Same as Siphon A	Construction
6	Siphon C	Same as Siphon A	Construction
7	Siphon D	Same as Siphon A	Construction
8	Reservoir	Construct two (2) to three (3) lined reservoirs	Design

Table 109
Waiāhole Ditch Irrigation System
2004-2014 Capital Improvement Projects

Item	Improvements	Status (2014)
Reservoir	Designed improvements to reduce water loss in reservoirs and installed two (2) Parshall flumes to monitor flow	Completed
Reservoir	Designed Waiāhole Irrigation System Reservoir improvements	Completed
Reservoir	Installed backup pump system at Reservoir 225	Completed
Reservoir	Designed water loss improvements for Reservoirs 225 and 155	Completed
Distribution	Closed 800 feet of unlined wing ditch (not in use)	Completed
Land	Acquired land parcels in Kahana and Waiāhole	Completed
Maintenance	Installed two new culvert pipes to replace two collapsed wooden flumes due to heavy rains in December 2008	Completed
Maintenance	Dredged bypass ditch at Reservoir 155 and implemented soil erosion control measures	Completed

The Waiāhole System requires additional projects to maintain water flow to the service area. The proposed projects were determined by field visits and discussions with ADC staff. The following projects are proposed and summarized in Table 110.

- Rehabilitation of access road and security fencing. The access road to the intake tunnel near Waimā stream crossing has been washed out and eroded due to heavy rainfall events. This repair was not anticipated in the annual maintenance budget, so funds were moved from other maintenance projects to repair the access road. The erosion will continue during heavy rainfall events, and annual maintenance costs will continue to increase. The washouts are caused by the accumulation of debris and rocks, formed due to overgrowth of invasive Albizia trees and other vegetation in the primary streambed. The new island diverts water toward the road, a natural low point, causing erosion at the roadway and adjacent areas.

This project recommends the removal of vegetation and debris to re-open the natural stream channel and accommodate the stream flow. In addition, it will provide structural reinforcement for the road and bridge to minimize damage from large river flows. During the development of this project, HDOA and ADC should work with the Hawaiʻi Housing Finance and Development Corporation (HHFDC) to reinforce the McCandless pipeline crossing the stream.

In addition, the roadway requires re-grading to restore proper drainage and minimize ponding and washout potential. New security fencing and gates also are needed to prevent public access into the system.

- Pipeline Installation 1. Install 300 feet of HDPE or similar pipe to prevent storm water intrusion, and mitigate wall collapse and root intrusion into the existing ditch structure.

- Pipeline Installation 2. Install 1,000 feet of HDPE or similar pipe to mitigate illegal dumping, prevent attractive nuisance liability, and prevent ditch wall collapse.

- Pipeline Installation 3. Install approximately three (3) miles of HDPE or similar pipeline through Mililani Town to mitigate illegal dumping, and prevent attractive nuisance liability, root intrusion, and wall collapse.

- Repair and/or replace damaged ditch lining at various locations. The approximate cumulative length of the damaged sections is 1.5 miles (not contiguous sections).

- SCADA monitoring system. Install a SCADA system with solar power. The system is planned to have seven (7) stations: four (4) located on the Windward side to monitor intake water flow and three (3) located on the Leeward side to measure ditch flow.

- Retrofit portions of the irrigation system with pipelines.

Table 110
Waiāhole Ditch Irrigation System
2018 Capital Improvement Projects

Project Description	ESTIMATED COST (2018 dollars)	
	Phase I	Phase II
Security and access	$2,100,000	
Pipeline installation 1	$110,000	
Pipeline installation 2	$220,000	
Pipeline installation 3		$3,300,000
Rehabilitation of ditch structure	$1,100,000	
SCADA	$2,200,000	
Retrofit with pipeline		
Design		$1,100,000
Construction		To be determined

4.3 PRIVATE SYSTEMS STUDIED IN THE 2004 AWUDP

The 2004 AWUDP studied four (4) privately managed irrigation systems:

- Kaua'i Coffee Irrigation system, Kaua'i;
- East Maui Irrigation System, Maui;
- Wailuku (West Maui) Irrigation System, Maui; and
- Maui Land and Pineapple/Pioneer Mill Irrigation System, Maui.

Unfortunately, updates for these systems are not available, as the **Maui Land and Pineapple** portion of **Pioneer Mill Irrigation System** and **Kaua'i Coffee** did not return our request to update the study by the time of publication.

Both **East Maui Irrigation System** and **Wailuku (West Maui) Irrigation System** have declined to provide updates due to ongoing legal proceedings. The Nā Wai ʻEhā ruling in April 2014 set interim instream flow standards (IIFS) for Waiheʻe River, ʻĪao Stream, North and South Waiehu Streams, and Waikapu Stream, all of which contribute to Wailuku Irrigation System. Having set the IIFS for the Nā Wai ʻEhā streams, the Commission began the task of making allocations to specific users through the issuance of water use permits. More than 100 water use permit applications have been filed. However, allocation decisions are complicated because claims of appurtenant rights to Nā Wai ʻEhā waters are made by the scores of claimants. In preliminary proceedings related to appurtenant rights, more appurtenant rights claims were filed than had been anticipated by IIFS proceedings. To further complicate matters, HC&S announced in January 2016 that it was transitioning from sugar cane cultivation to diversified agriculture by the end of that year. Nā Wai ʻEhā appurtenant rights, water allocations, and IIFS continue to be adjudicated through contested case proceedings.

The IIFS for several streams that contribute to East Maui Irrigation System also continue to be litigated. Following contested case proceedings, the hearing officer transmitted a recommended decision to CWRM at the end of 2015. Shortly thereafter, HC&S made the transition announcement mentioned above. The IIFS contested case is being re-opened to consider this new information before CWRM renders a decision on the IIFS for these East Maui streams. Refer to Section 7.5 for additional information on the litigation.

The gage reports for the East Maui and Wailuku irrigation systems are shown on Tables 111 and 112, respectively. Both systems provide water to IAL with an anticipated water demand from the Petition and Decision and Order of 195 MGD.

Table 111
East Maui Irrigation System
Reported Flows
(Hawaiian Commercial & Sugar Company)

Gage Location	Hist. Ave. Flow [2] (MGD)	USGS [1] Location Date range	USGS [1] Est. Mean Monthly Discharge (MGD)		Reported [3] Monthly Average Flows at Gage Locations (MGD)					
					2012 (11 months)		2013		2014	
			low	high	low	high	low	high	low	high
(old) Hāmākua	[65]	Honopou near Huelo 1918-1965	0.8	4.2						
Spreckels (old Ha'ikū)	[30]	below Kaaiea near Huelo 1918-1929	2.9	8.4						
		At Haipua'ena	--	--	3.2	18.4	3.1	32.8	3.1	20.6
		At Wailuku	--	--	6.8	19.4	0.0	25.4	10.7	25.7
Lowrie	[45]	Honopou near Huelo 1910-1985	18.1	30.3	6.5	20.7	0.0	15.8	2.1	20.3
		At Kailua	--	--	3.6	21.4	0.0	13.3	2.3	25.4
		At Māliko	--	--	7.4	16.2	0.0	13.7	4.2	16.2
New Hāmakuā	[54]	Honopou near Huelo 1918-1985	14.9	36.8	0.9	32.3	0.0	20.5	3.3	27.6
Ko'olau	[55]	Wahinepee near Huelo por. 1922	21.3	98.2						
		At Ke'anae	--	--	20.0	79.3	0.0	86.5	18.6	64.1
		At Nāhiku	--	--	7.7	39.7	0.0	31.6	0.0	40.0
New Ha'ikū	[45] 25	Honopou near Kailua 1910-1985	11.0	25.9	1.3	13.6	0.0	13.3	0.6	14.2
		At Māliko	--	--	3.9	32.5	0.0	15.6	4.2	16.7

TABLE 111 (continued)
East Maui Irrigation System
Reported Flow
(Hawaiian Commercial & Sugar Company)

Gage Location	Hist. Ave. Flow (2) (MGD)	USGS (1) Location Date range	USGS (1) Est. Mean Monthly Discharge (MGD)		Reported (3) Monthly Average Flows at Gage Locations (MGD)					
					2012 (11 months)		2013		2014	
			low	high	low	high	low	high	low	high
Kauhikoa	[71]	ʻŌpana Weir 1910-1928	9.0	22.0						
		At Māliko	--	--	2.5	32.8	0.0	22.8	3.6	28.6
Wailoa	[110]	Honopou near Huelo 1922-1987	88.5	135.1	43.5	147.0	0.0	148.3	34.2	170.9
		At ʻŌpana	--	--	44.4	151.1	0.0	150.5	50.3	171.8
Waiheʻe Ditch	--	At Field 63	--	--	7.0	18.0	0.0	20.2	5.1	18.6

1) USGS Surface – Water Monthly Statistics for the Nation (http://waterdata.usgs.gov/nwis)
2) Source: Wilcox, Carol, 1977
Hist. Ave. Flow - Historical Average Flows, based on the historical record
Cap. - Capacity (unless otherwise noted)
3) Reports are from Commission on Water Resource Management and could contain estimates and incomplete records, and exact location of measurements are not reported.

Table 112
Wailuku Water Company
Reported Flows

Gage Location	Hist. Ave. Flow (2) (MGD)	USGS (1) Location Date Range	USGS (1) Est. Mean Monthly Discharge (MGD)		Reported (3) Monthly Average Flows at Gage Locations (MGD)					
					2012 (partial)		2013 (partial)		2014 (partial)	
			low	high	low	high	low	high	low	high
Waihe'e Ditch (Spreckels)	[10] 10-2	--	--	--						
Waihe'e Canal (Ditch)	[27] 27	--	--	--						
Everett Ditch Waikapū Stream					0.0	0.0	0.0	0.0	0.0	0.0
Field #1 Waihe'e Stream					0.0	0.0	0.0	0.0	0.0	0.0
'Īao-Māniania Ditch 'Īao Stream					0.9	2.5	0.5	2.7	0.4	1.7
'Īao -Waikapū Ditch 'Īao Stream					5.0	15.8	7.1	15.2	6.4	17.1
Kama Ditch 'Īao Stream					0.0	0.0	0.0	0.0	0.0	0.0
North Waiehu Ditch Waiehu Stream					0.0	0.0	0.0	0.0	0.0	0.0
Reservoir #6 Waikapū Stream					0.0	0.0	0.0	0.0	0.0	0.0
South Waikapū Ditch-Waikapū Str.					1.0	1.4	1.2	1.6	1.2	1.8
Spreckels Ditch Waihe'e Stream					5.2	10.5	4.3	8.4	3.5	9.5
Waihe'e Ditch Waiehu Stream					0.0	0.0	0.0	0.0	0.0	0.0
Waihe'e Ditch Waihe'e Stream					12.3	23.3	10.3	22.1	10.8	31.5
Waihe'e Ditch Waikapū Stream					1.1	18.1	0.3	2.1	0.1	1.7

1) USGS Surface – Water Monthly Statistics for the Nation (http://waterdata.usgs.gov/nwis)
2) Source: Wilcox, Carol, 1977. Hist. Ave. Flow - Historical Average Flows, based on historical records
Cap. - Capacity (unless otherwise noted)
3) Reports are from Commission on Water Resource Management and could contain estimates and incomplete records, and exact location of measurements are not reported.

4.3.1 PIONEER MILL IRRIGATION SYSTEM (HONOKĀHAU) – WEST MAUI LAND CO.

A portion of the Honokāhau Irrigation ditch (Pioneer Mill Irrigation System) belongs to West Maui Land Co. and provided insights into its agricultural land use. Water does not currently flow into the West Maui Land Co. portion of the ditch due to the decommissioning of the Wahikuli Reservoir and issues upstream of the reservoir. The gage reports for the Maui Land and Pineapple/Pioneer Mill Irrigation System are presented on Table 113. In Table 114 are the CIP projects that may have impacted the West Maui Land Co. section of the ditch and their status.

The alignment of the Honokāhau ditch through the West Maui Land Co. property is shown in Map 125. The potential service area is approximately 1,000 acres of agricultural land owned by KSBE, as well as approximately 400 acres of agricultural land owned by West Maui Land Co. The agricultural land mauka (north) of the ditch is supplied by private water companies that draw water from various surface and ground water sources. However, if the Honokāhau ditch was to reopen, the irrigation water could be used as backup water for these mauka farms that have approximately 1,200 acres of diversified agriculture.

One development is the Makila Land Co., LLC, which offers a range of agricultural lot sizes and configurations for a variety of agricultural uses.[18] The Makila project encompasses 4,500 acres stretching from Honoapi'ilani Highway to the West Maui Mountains. The agricultural portion includes 19 15-acre lots, 24 five (5)-acre lots and nine (9) lots ranging between 25 to 65 acres. In the future, new developments may include agricultural lots ranging from 15 to 65 acres.

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[18] http://www.westmauiland.com/index/, accessed August 2015.

Table 113
Maui Land and Pineapple/Pioneer Mill Irrigation System
Reported Flows
(including reports from West Maui Land Company)

Gage Location	**Hist. Ave. Flow**[(2)] (MGD)	**USGS**[(1)] **Location Date range**	**USGS**[(1)] **Est. Mean Monthly Discharge** (MGD)		**Reported**[(3)] **Monthly Average Flows at Gage Locations** (MGD)					
					2012 (partial)		**2013 (partial)**		**2014 (partial)**	
			low	**High**	**Low**	**high**	**low**	**high**	**low**	**High**
Honokāhau	[35] 20	At Intake nr. Honokāhau 1907-1913	19.4	22.6	--	--	--	--	0.5	19.1
Kaua'ula	4.5	nr. Lahaina 1912-1917	5.1	6.5	2.0	4.0	1.6	5.7	1.2	4.1
Olowalu	4	nr. Olowalu 1911-1967	3.8	5.5	1.0	1.6	1.1	3.6	1.4	2.1
Honolua	[50] 30-18				--	--	--	--	0.0	0.0
Honokōwai	6									
Kahoma	3				0.1	0.3	0.2	1.0	0.3	0.8
Kanahā	3.8									
Launiupoko	0.8				0.2	0.7	0.3	0.7	0.3	0.8
Ukumehame	3									
Wahikuli	[5]									
Kaluanui					--	--	--	--	0.0	0.0

Table 113 (continued)
Maui Land and Pineapple/Pioneer Mill Irrigation System
Reported Flows
(including reports from West Maui Land Company)

Gage Location	Hist. Ave. Flow (2) (MGD)	USGS (1) Location Date range	USGS(1) Est. Mean Monthly Discharge (MGD)		Reported(3) Monthly Average Flows at Gage Locations (MGD)					
					2012 (partial)		2013 (partial)		2014 (partial)	
			low	High	Low	high	low	high	low	High
Agriculture Irr.					0.2	1.2	0.3	0.8	0.0	0.4
'Awalau 4"					0.0	0.2	0.0	0.1	0.0	0.1
DWS Māhinahina					1.0	2.2	1.6	2.1	0.0	1.7
Kā'anapali Dev. Co.					3.5	13.0	3.4	6.2	0.0	5.9
Kapalua Water Irr.					0.9	1.7	0.9	1.5	0.0	0.6
Nāhiku Stream Pump					0.0	0.0	0.0	0.0	0.0	0.0
'Ōpana 12"					0.0	0.7	0.0	0.4	0.0	0.4
'Ōpana 2.5"					0.0	0.0	0.0	0.1	0.0	0.0
Troon (golf)					0.6	1.1	0.7	1.3	0.0	0.4

1) USGS Surface – Water Monthly Statistics for the Nation (http://waterdata.usgs.gov/nwis)
2) Source: Wilcox, Carol, 1977
   Hist. Ave. Flow - Historical Average Flows, based on the historical record
   Cap. - Capacity (unless otherwise noted)
3) Reports are from Commission on Water Resource Management and could contain estimates and incomplete records, and exact location of measurements is not reported. Reported by West Maui Land Company, Inc.

TABLE 114
West Maui Land Co. Portion
2004 Proposed Capital Improvement Projects

No.	Item	Description	Status
1	"New Reservoir"	Remove silt; install base course, geotextile, and HDPE lining	Not Completed
2	Wahikuli Reservoir	Dewater, remove silt; install pipe bypass, base course, geotextile and HDPE lining; Level II dam hazard assessment	Reservoir Decommissioned
3	Pump "M"	Remove pump house and pumps; install three (3) new pumps, 10-inch Ductile Iron (DI) pipe & 10-inch HDPE pipe, new building, fence and gate; reactivate electrical service	Shut Down

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CHAPTER 5
PROPOSED NEW IRRIGATION SYSTEMS

To make agriculture sustainable, the grower has got to be able to make a profit.
Sam Farr

This chapter presents suggestions for potential growth of diversified agriculture based on the proposed development of new water systems and offers studies to investigate the viability of these new water systems. As these potential (suggested) systems are preconceptual, details such as water rights, ownership, management, and construction costs have not been determined. In addition, when these new water system(s) are ripe for decision-making, the feasibility, environmental, and/or cost-benefit studies will be performed as required.

The development of these new water systems would benefit the State by expanding diversified agriculture acreage. Expanding diversified agriculture is especially pressing because Hawai'i imports approximately 98 percent of its commodities.[19] In addition, State policymakers and the community have called for sustainability and self-sufficiency, which is directly related to diversified agriculture.

During the interview process and data collection, farmers and ranchers highlighted two (2) commodity groups that have the potential to grow diversified agriculture production. These two (2) commodity groups were truck farming and grass-fed beef. The increase in production of these commodities would support the state's goals of food sustainability and, to a lesser extent, import replacement. One of the key issues that inhibits the expansion of these commodities in the proposed growing areas is the lack of water resources.

Section 5.1 provides a brief overview of areas that have the potential to increase truck farming acreage. Section 5.2 provides a brief definition of grass-fed beef and the areas for potential expansion. Section 5.3 provides a CIP to investigate the potential to develop these new systems and agriculture areas.

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[19] Laney, Leroy O., *The Impact of Hawai'i's Harbors on the Local Economy*, May 2007.

5.1 POTENTIAL TRUCK FARMING AREAS

Farmers have proposed an increase in irrigated acreage for truck farms in the Kula area of Maui, and the Lālāmilo and Kawaihae areas of Hawai‘i. The Kula and Lālāmilo areas are two (2) of the best-producing areas in the state. The suggested areas are shown on Exhibit 30.

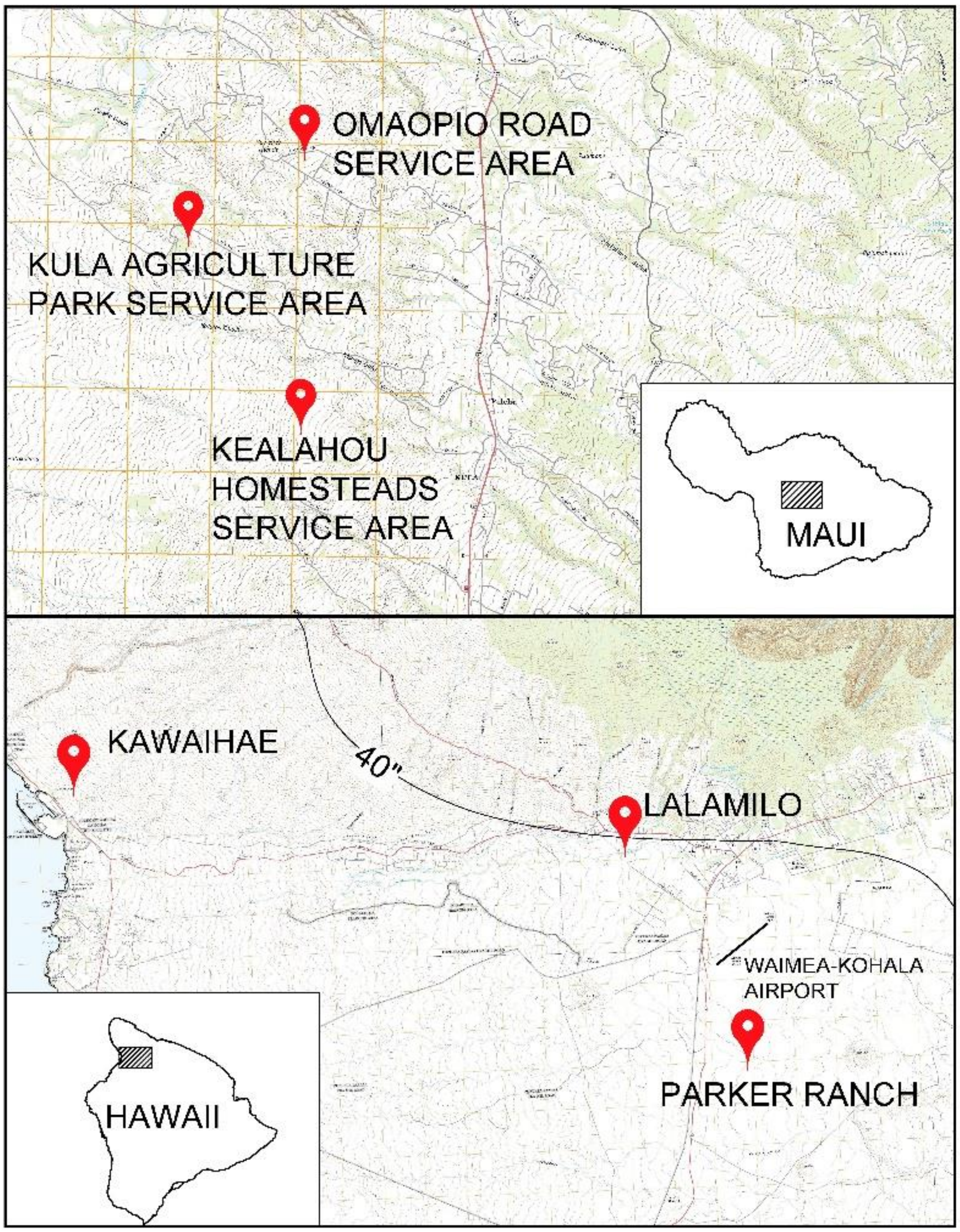

Exhibit 30. Potential Truck Farming Areas on Maui and Hawai‘i.

5.1.1 POTENTIAL KULA EXPANSION

The Kula area of Maui County has been subjected to various degrees of drought throughout its history. The *Kula Stormwater Reclamation Study* (KSWRS) was conducted by the Central Maui Soil and Water Conservation District, with technical assistance provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The KSWRS is a set of four (4) reports: 1) an inventory and assessment of agricultural water needs, sources, and facilities; 2) a drought-mitigation resource analysis; 3) development of alternative concepts; and 4) an alternatives assessment, which included identification of economic, social, and environmental issues.

The major goals of this study were:

- An assessment of the drought-period agricultural water needs of the agricultural producers in the Lower Kula region;
- A survey of the existing and potential agricultural water supply sources and distribution facilities;
- An assessment of stormwater capture and storage potential in Kula and surrounding areas;
- A formulation of alternatives involving stormwater reclamation to reduce drought-related damage to crops and livestock, and to improve agricultural drought resiliency; and
- An evaluation of the economic, social, and environmental effects of implementing the drought-mitigation alternatives.

The KSWRS studied both the agricultural service and water supply areas. The agricultural service area covers approximately 1,338 acres of active[20] cropland or agricultural land within the area from the 1,200-foot to the 3,500-foot elevation, and from Pi'iholo Road to Nā'alae Road. The potential water supply area extends from Ke'anae Gulch to Nā'alae Gulch, running from 1,000-foot to 4,400-foot elevation. The service area includes 336 acres in the Upper Kula area and 1,002 acres in the Lower Kula area. An additional 250 acres of land near Ōma'opio being used by Hāli'imaile Pineapple Company has the potential to be serviced. To determine the water demand, KSWRS based the analysis

[20] Active farmland and cropland are considered lands that are currently being farmed.

on three (3) rainfall conditions — normal, drought, and severe drought — and the results are shown in Table 115.

The KSWRS forecast a 25-percent increase in crop acreage, equivalent to 335 acres, if water was available. The increase includes 84 acres in the Upper Kula area and 251 acres in the Lower Kula area. The study computed the future water demand based on rainfall conditions and the forecast increase of crop acreage. The increased acreage would require 217 million gallons per year (MG/yr) of irrigation water during normal rainfall years and 246 MG/yr of irrigation water for drought years. Table 116 summarizes the present and future agricultural acreages and water demand.

Table 115
Average Daily Irrigation Water Requirements
Kula Farms

	Upper Kula Farms			**Lower Kula Farms**		
	Normal Rainfall (Median)	**Drought**	**Severe Drought**	**Normal Rainfall (Median)**	**Drought**	**Severe Drought**
Average Daily Water Requirement (gpd/acre)	2,577	3,029	3,221	3,889	4,371	4,577
Peak Daily Water Requirement (gpd/acre)	4,093	4,294	4,416	5,711	5,930	6,063

Reference: Mink and Yuen, *Kula Stormwater Reclamation Study*, 2007

The preferred alternative included two (2) development system options as shown on Exhibit 31:

- System 1 - basic conceptual layout with a standalone reservoir; and
- System 2 - basic conceptual layout with two (2) standalone reservoirs.

The two (2) development options have the following characteristics:

- Captures excess water from the Piʻiholo Reservoir during rainy season rainfall events and other storm events;
- Utilizes existing easements and rights-of-way for the distribution system; and
- Avoids construction of storage and distribution systems in Conservation District lands.

Table 116
Present and Future Agricultural Acreages and Water Demand

DWS Systems	Present Acres (active)	Normal Rainfall Water Demand (MG/yr)	Drought Rainfall Water Demand (MG/yr)	Future Acres	Normal Rainfall Water Demand (MG/yr)	Drought Rainfall Water Demand (MG/yr)
Upper Kula	336	158.0	185.7	420	197.6	232.2
Lower Kula	1,002	711.1	799.4	1,253	888.8	999.2
Ōmaʻopio	250	--	--	--	--	--
Total Kula	1,338	869	985	1,673	1,086	1,231
Total	1,588	--	--	--	--	--

Reference: Mink and Yuen, *Kula Stormwater Reclamation Study*, 2007
Notes: DWS - Maui County Department of Water Supply
Normal rainfall year - 50 percent probability
Drought rainfall year - 80 percent probability

System 1 utilizes a large reservoir with a storage capacity between 150 MG to 300 MG on open pastureland owned by Haleakalā Ranch. This reservoir would be located between the 2,200-foot to 2,600-foot elevations.

System 2 utilizes two (2) reservoirs on Haleakalā Ranch lands: one (1) in the Kailua area and one (1) in the Pulehunui area. The Kailua reservoir would have a storage capacity between 130 MG to 150 MG and be located between the 2,500-foot and 2,600-foot elevations. The Pulehunui reservoir would have a storage capacity of 150 MG and be located between the 2,650-foot and 2,700-foot elevations.

The System 2 option would irrigate 80 acres more of diversified agricultural land than System 1. Due to the higher elevation of the System 2 reservoirs, there also is potential to irrigate an additional 2,000 acres of pastureland when compared to the System 1 option.

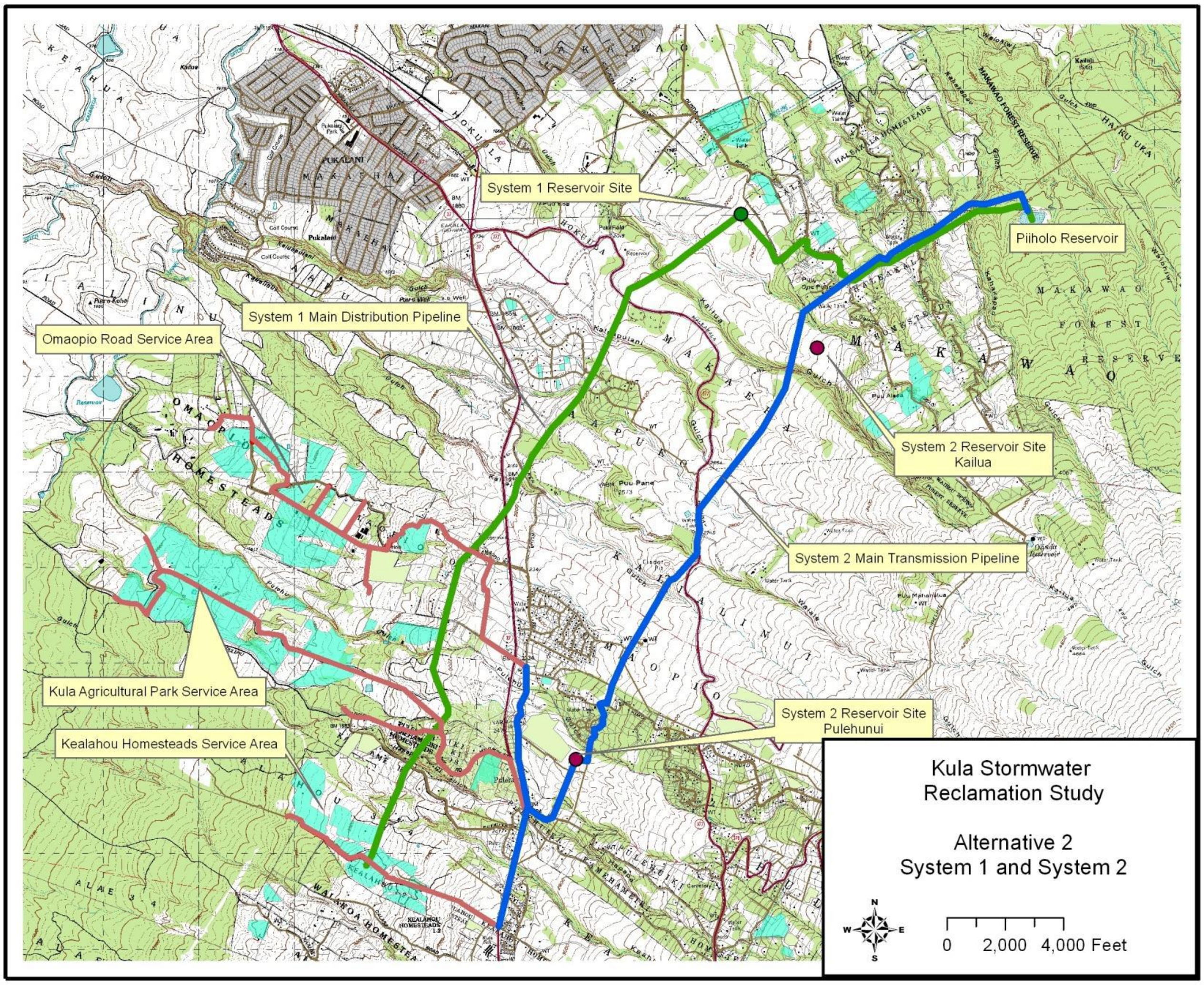

Exhibit 31. Kula System Preferred Alternatives (Mink and Yuen, *Kula Stormwater Reclamation Study*, 2007)

5.1.2 POTENTIAL - LĀLĀMILO AND WAIMEA EXPANSION

Farmers in the area would like to expand the Lālāmilo Farm lots as originally planned and/or develop certain Parker Ranch lands for diversified agriculture. Informal discussions with Parker Ranch indicated a willingness to consider using certain portions of the ranch for diversified agriculture. At that time, the area suggested by Parker Ranch for diversified agriculture is located south of Waimea-Kohala Airport.

One of the constraints for developing these areas is the supply and distribution of water. Based on the 2004 AWUDP, water demand in this area is approximately 3,400 gpd/acre. The following concepts were suggested for consideration:

- Expansion of the Upper Hāmākua (Waimea) Ditch System;
- A new reservoir and agricultural water system; and
- Conversion of the current County of Hawai'i Department of Water Supply potable water system to a nonpotable system, and replacement of a new potable water system with a well and reservoir system.

The first alternative would develop a new distribution system from the Upper Hāmākua Ditch System. However, current distribution of water from the Upper Hāmākua Irrigation System is limited to its existing users, and any expansion would require approval by the Board of Agriculture.

The expansion may require an increase in the water supply, distribution lines, and possibly new reservoirs. If the expansion area neighbors the existing Lālāmilo farm lots, the distribution system may connect to the existing Lālāmilo water system. If the expansion area is south of Waimea-Kohala Airport, an extension of the main transmission pipeline will be required along the Old Māmalahoa Highway.

The second alternative would be to develop a new system, including source development, water storage, and a distribution system. In the past, there was a plan to develop a new reservoir and distribution system north of Waimea town on DHHL property. However, this plan was not implemented.

The third alternative would be to convert the current Waimea potable water system to a well reservoir(s) system, providing the Hawai'i County of Department of Water Supply finds a suitable aquifer to develop. The existing potable water system is a surface water system and can be converted for agricultural use. The initial studies will need to find a suitable aquifer, as well as negotiations between the County of Hawai'i and the system developer. A previous study, the *Lālāmilo Water System, Revised Environmental Impact Statement*[21], described a similar system.

5.2 POTENTIAL GRASS-FED BEEF AREAS

The ranchers and landowners have stated that there is an increased consumer demand for grass-fed beef, and they currently are having difficulty maintaining a consistent and high-quality supply. Interviews[22] with several commercial consumers support the need for consistent supply, taste, and quality.

The USDA certified grass-fed beef under their *Grass-fed Label* until 2016. The certification stated that animals must be fed only grass and forage for its lifetime, with continuous access to pasture during the growing period. In addition, regular grass supply will provide better consistency of taste and quality to the market. To accomplish this, the pastureland needs to have finishing and managed pastures. The finishing pastures will be used to prepare the animals for market. Many of the pasturelands need to be managed to provide the animal with continuous access to good grazing areas. Typically, grass-fed cattle will require approximately 2 acres per head, depending on the quality of the pasture and ranching technique. Most of the pastures will need to be irrigated.

The ranchers suggested the following areas for consideration to increase grass-fed beef production: North Kohala, Kawaihae, and between Pu'u Kapu

[21] State of Hawai'i, Department of Land and Natural Resources, *Lālāmilo Water System, South Kohala, Revised Environmental Impact Statement,* March 1980.
[22] Personal communication.

to Āhualoa. The proposed areas for additional grass-fed beef pastures are shown in Exhibit 32.

5.2.1 POTENTIAL NORTH KOHALA EXPANSION

One of the mainstays of the agricultural industry in the North Kohala district is cattle, with one of its main commodities being grass-fed beef. To increase production of grass-fed beef, there needs to be an increase in acreage for managed pastures, irrigated pastures, and general pastures. Ranchers suggest irrigating the area below the 40-inch rainfall isohyet.

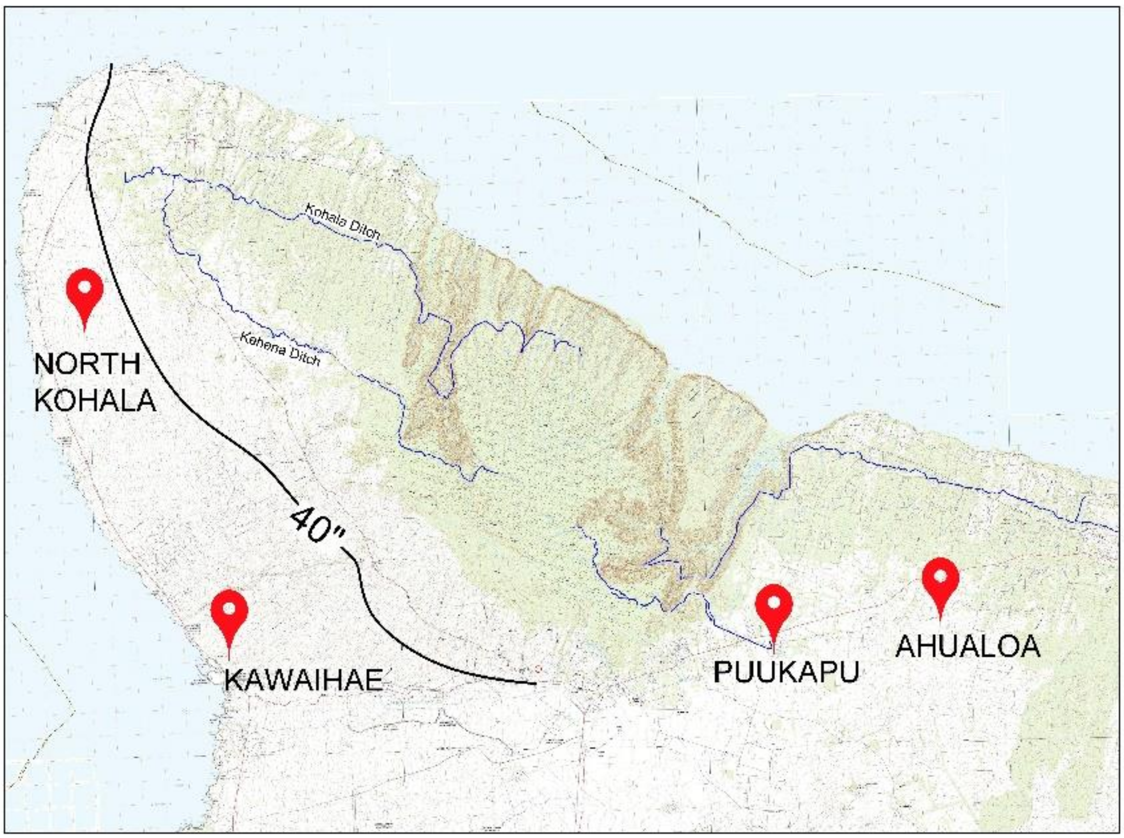

Exhibit 32. Potential Areas for Managed and Irrigated Pastures.

Notable irrigation systems in the North Kohala district are the Kohala and Kehena ditches. One of the recommendations for the rehabilitation of the Kehena Ditch system includes reopening an unused intake to increase flow into the system. Another suggestion from the ranchers to increase agricultural water supply is to transmit water from the Kohala Ditch system. It should be noted that during the plantation era, the Kehena and Kohala ditches were connected, with the Kehana Ditch system supplying water to the Kohala Ditch system.

If an increase in irrigation acreage is required, a new distribution system will be necessary. Both the new and existing distribution system should be constructed using a pipe system, as system loss for an open ditch system is significant.

5.2.2 POTENTIAL PU'U KAPU TO ĀHUALOA EXPANSION

Ranchers suggest that the area from Pu'u Kapu to Āhualoa be developed for managed pastures and "finishing" pastures. These pastures would enable consistent, quality beef to be produced in this area. The following concepts were suggested as possible alternatives to increase the water supply to this area:

- Divert water from the Lower Hāmākua Ditch system, which will require a pump system[23];
- Develop a new system that draws water from either the Kohala or East Mauna Kea hydrographic units; or
- Divert and increase water capacity of the Upper Hāmākua Ditch Irrigation System.[24]

5.2.3 POTENTIAL KAWAIHAE EXPANSION

The land areas east and north of Kawaihae Harbor are agricultural lands that have limited production due to lack of water. This area was historically known for sweet potato cultivation, with water being diverted by 'auwai from a gulch that runs only intermittently today. Therefore, if water systems for other areas of South and North Kohala are being studied, these studies should include Kawaihae as part of the service area. The agricultural potential is

[23] In 2014, ACT 233 mandated the toll on water provided by the Lower Hāmākua Ditch shall not exceed 20 cents per 1,000 gallons.

[24] USGS map of the area shows a tunnel and ditch system that connected Pu'ukapu Reservoir to Āhualoa.

unknown, as it is currently used for cattle grazing and historically for crop cultivation.

5.3 PROPOSED CAPITAL IMPROVEMENT PROGRAM

The development plan proposes additional studies to investigate the potential of these new systems and agricultural areas. The CIP program is summarized in Table 117. The CIP proposes projects for truck farming and grass-fed beef expansion areas in Hawai`i. As these are suggested systems, the proposed projects are conceptual planning studies to investigate the potential of these new areas, including the stakeholders and users. If a decision is made to pursue the development of a new or expanded agricultural new water system in these area(s), then additional feasibility and planning will be performed to determine the land area, system ownership and management, land availability, water demand, water source, etc.

For the truck farming area at Kula, Maui, the CIP proposes a feasibility study to update the information in the KSWRS and also include information such as, but not limited to, water source(s), system ownership and management, and implementation options and schedule. The design and construction would be determined upon completion of the feasibility study and when funds are available.

Table 117
Estimated Costs for Potential Water System(s)
Kohala and Hāmākua Regions

Capital Improvement Project	**Estimated Cost** (2018 dollars)
Truck Farming	
Conceptual planning study Lālāmilo and Waimea expansion, including Kawaihae	$500,000
Feasibility, planning, design, construction	To be determined
Feasibility, source, ownership study Kula	$5,000,000
Planning, design, construction	To be determined
Grass-fed Beef	
Conceptual planning study North Kohala, including Kawaihae	$500,000
Feasibility, planning, design, construction	To be determined
Conceptual planning study Pu'u Kapu to Āhualoa	$500,000
Feasibility, planning, design, construction	To be determined

CHAPTER 6
AGRICULTURAL WATER DEMAND

When the well's dry, we know the worth of water.
Benjamin Franklin

Agricultural "water demand," as defined by HDOA-ARMD, is the quantity of water supplied to farms from agricultural irrigation systems (ditches). In comparison, CWRM applies the term "water duty," which is the quantity of irrigation water required for a crop to mature. Note that neither "water duty" or "water demand" values can be used to set diversion allowances.

In this study, the term "water demand" will refer to water use as measured at the farm's boundary or water meter. From an irrigation standpoint, this demand is the "gross irrigation requirement," as it includes system losses and other non-irrigation water uses occurring within the farm area. Within the farm, non-irrigation uses include pest control strategies, cleaning of product, etc. The net irrigation requirement is the amount of water that reaches the crop. It is also referred to as the consumptive use, or the crop's water duty.

6.1 HISTORICAL PERSPECTIVE

The pre-contact population (prior to 1778 A.D.) engaged in subsistence agriculture, cultivating crops like taro and raising livestock such as pigs and dogs. The estimated pre-contact population total ranged from 200,000 to 800,000, with some estimates closer to 1 million people (Kirch 2007b).[25] According to Kirch (1982), the population probably started to decline about 100 years before contact with Westerners.

As the population increased over time, agricultural areas expanded and intensified. To meet the increase in water demand, agricultural stakeholders developed irrigation systems that included stream diversions, spring

[25] As referenced in Lagenfoged, et. al., Kirch, P.V., 2007b. "Like Shoals of Fish": archaeology and population in pre-contact Hawai'i. In: Kirch, P.V., Rallu, J. (Eds.), The Growth and Collapse of Pacific Island Societies: Archaeological and Demographic Perspectives. University of Hawai'i Press, Honolulu, pp. 52–69.

diversions, and ditches. The oldest known irrigation system is the Moloka‘i agricultural irrigation system, with an estimated creation date of 1200 A.D. Archaeological studies have shown that between 1200 A.D. to 1650 A.D., there was significant development of large-scale irrigation and permanent field systems (Cuddihy and Stone, 1990). Pre-contact era agricultural systems are generally categorized into four types (Kurashima and Kirch, 2011):

- irrigated pondfield;
- rain-fed dryland;
- colluvial slope cultivation; and
- aquaculture.

Irrigated pondfield agriculture supported the intensive cultivation of taro in large-scale agricultural development. Water demand for the cultivation of taro has been estimated at 280,000 liters/hectare per day.[26] This water demand was referred to as the "Hawaiian Legal Requirement" (de la Pena, 1983), or the minimum legal requirement by others. Spriggs (1984) stated that irrigated agriculture requires about half the labor of non-irrigated agriculture, or about 437.5 workdays/hectare per year.

Lagenfoged, et. al. (2009) estimated that 190 square kilometers (46,950 acres or 19,000 hectares) were cultivated using irrigated agriculture in pre-contact Hawai‘i. Based on the 19,000 hectares used for taro production and taro irrigation’s legal requirement, total statewide water demand was approximated at 1.4 billion gallons per day.[27] Based on the modeling results, the required labor input was approximately 240,000 people for all agricultural crops. Due to this large labor requirement and the intense nature of the agriculture activity, large population centers developed near these agricultural areas.

The arrival of European and American ships increased the bartering of Hawaiian agriculture commodities for imported iron and manufactured items. Typical agricultural commodities used in bartering included pigs, bananas, taro, and sweet potatoes.

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[26] 280,000 liters/hectare per day is approximately 30,000 gallons/acre per day.
[27] Using today’s taro irrigation values of 260,000 gpd/acre, that 46,950 acres would be using approximately 12.2 billion gallons per day.

6.2 PAST STUDIES AND ANALYSIS

Between 1953 to 2011, it has been reported that the water demand for agriculture in Hawai'i ranged from 1,131 to 8,035 gpd/acre. Water demand for an assortment of crops from various studies is shown in Table 118. Past studies have presented water demand and production of diversified agriculture crops from the 1930s to present.

In 1933, Wadsworth[28] published *A Historical Summary of Irrigation in Hawai'i*, which documented the transition from pre-contact irrigation practices to those used for modern sugar production. Wadsworth marks the modern period of water utilization at 1878 due to economic and political developments. In the document, it is noted that immigrant laborers from Japan, particularly from Fukuoka and Kumamoto prefectures, were skilled in the dangerous work of tunneling. One of the outstanding laborers was Nitaro Kawano, who constructed 24 tunnels in the Olokele system on Kaua'i in 1903.

In 1938, the University of Hawai'i, Agricultural Extension Service prepared Land Utilization Maps, which were reprinted as MacLennan's *Sovereign Sugar, Industry and Environment in Hawai'i,* 2014. Acreages for various land uses are summarized in Table 119. The land use study found that grazing commanded the largest land use at 2,080,000 acres, while other agricultural uses occupied 308,895 acres. For comparison purposes, the land use for 2012 from the National Agricultural Statistics Service is included in Table 120.

[28] Wadsworth, H. A., *A Historical Summary of Irrigation in Hawai'i,* The Hawaiian Planters' Record, Vol. XXXVII, No. 3, Third Quarter, 1933.

Table 118
Comparison of Agricultural Water Demand

Year	Water Demand (gpd/acre)	Comment
1953 (Reference 41)	5,325	Kailua and Kāneʻohe, Oʻahu
1956 (Reference 15)	1,131 2,277	Waimānalo Waimānalo - dry
1959 (Reference 13)	7,140 to 8,035	Sugar cane
	1,000,000	Wet crops (rice, taro, etc.)
	1,340 to 4,465	Diversified agriculture (excluding sugar cane and pineapple)
1984 (Reference 64)	6,000 4,000	Kahuku - nursery Kahuku - truck orchard
1995 (Reference 46)	7,722	Sugar cane
1999 (Reference 51)	4,700	Reference Crop - normal rainfall for elevations under 500 feet
	5,300	Reference Crop - low rainfall for elevations under 500 feet
	3,500	Reference Crop - normal rainfall for elevations above 500 feet
	4,200	Reference Crop - low rainfall for elevations above 500 feet
2004 AWUDP	3,400	Lālāmilo
2011 (Reference 34)	2,577	Upper Kula - average rainfall
	3,029	Upper Kula - drought
	3,221	Upper Kula - severe drought
	3,889	Lower Kula - average rainfall
	4,371	Lower Kula - drought
	4,577	Lower Kula - severe drought

Table 119
Land Use Acreages in Hawai'i, 1937
Territorial Planning Board, Hawai'i
(Ripperton, Coulter, Moltzau)

Utilization	Acres* per County					
	Kaua'i	O'ahu	Maui	Hawai'i	Total	%
Sugar Cane	47,000	43,200	40,700	110,000	240,900	5.87
Pineapple	2,900	15,000	32,200	0	50,100	1.22
Grazing	177,000	107,000	406,000	1,390,000	2,080,000	50.72
Forest	149,000	120,000	196,000	562,000	1,027,000	25.04
Wet Crops (rice, taro, etc.)	1,170	1,275	220	285	2,950	0.07
Federal	80	36,700	17,700	145,000	199,480	4.86
Avocado	15	540	85	145	785	0.02
Banana	25	995	15	155	1,190	0.03
Field Crops	40	260	655	1,200	2,155	0.05
Other Fruit	30	128	35	135	328	0.01
Coffee	--	0	0	5,850	5,850	0.14
Nuts (macadamia)	200	72	15	530	817	0.02
Papaya	5	300	5	50	360	0.01
Vegetables	335	1,550	1,300	275	3,460	0.08
County Parks	1,900	2,880	570	675	6,025	0.15
Other	17,300	54,100	54,500	354,000	479,900	11.70
Total	397,000	384,000	750,000	2,570,000	4,101,000	

Note: *Acreage of some minor crops are estimated.

Table 120
Land Use Acreages in Hawai'i, 2012
(USDA, National Agricultural Statistics Service)

Utilization	1,000 Acres									
	Kaua'i		O'ahu		Maui		Hawai'i		TOTAL	
	1937	2012	1937	2012	1937	2012	1937	2012	1937	2012
Sugar Cane	47	<0.1	43.2	D	40.7	D	110	<0.1	240.9	D
Pineapple	2.9	<0.1	15.0	D	32.2	D	0	<0.1	50.1	D
Grazing	177	98.1	107.0	27.7	406.0	155.3	1,390.0	520.2	2080.0	801.4
Wet Crops (rice, taro, etc.)	1.2	nr	1,275.0	nr	0.2	nr	0.3	nr	nr	nr
Avocado	<0.1	D	0.5	<0.1	0.1	D	0.2	D	0.8	D
Banana	<0.1	D	1.0	D	<0.1	0.2	0.2	0.6	1.2	1.3
Field Crops	0.0	nr	0.3	nr	0.7	nr	1.2	nr	2.2	nr
Corn (grain)	nr	2.3	nr	D	nr	D	nr	0	nr	5.2
Other Fruit	<0.1	D	0.1	D	<0.1	D	0.1	D	0.3	2.8
Coffee	--	D	0	D	0	D	5.9	d	5.9	9.9
Nuts (macadamia)	0.2	<0.1	0.1	0.6	<0.1	<0.1	0.5	17.4	0.8	18.0
Papaya	<0.1	<0.1	0.3	0.2	<0.1	<0.1	<0.1	1.7	0.4	2.0
Vegetables	0.3	0.2	1.6	5.2	1.3	1.8	0.3	1.7	3.5	8.8

Note: D - Data withheld to avoid disclosure of a single farm
nr - not reported

In 1942, **Ripperton and Hosaka** published *Vegetation Zones of Hawai'i.* The original purpose of the study was to classify and identify zones for pastureland, but instead the effort documented the diverse forms of agriculture in Hawai'i (at the time, pasturelands were approximately one-fourth (1/4) of the state's land area). The collected information on agricultural cultivation formed the basis of delineated cultivation zones for each island.

Based on elevation, climate, soil, and vegetation, Ripperton and Hosaka characterized five (5) zones: A, B, C, D, and E. Within zones C, D, and E, the authors created subzones delineated at certain elevation contours. The vegetation zones depicted by Ripperton and Hosaka are shown on Exhibits 33 to 35.

The five (5) zones are described as follows.

- A - This zone is typically located on the lee side of an island and ranges from sea level to an elevation of 500 feet. Where water is available, the arable parts are used for sugar production and grazing.

- B - This zone lies above Zone A, unless it extends to the shoreline. The upper elevation limit is 2,000 feet, and the average annual rainfall ranges from 20 to 40 inches.

- C - This zone extends to an elevation of 4,000 feet. There is a distinct change in vegetation; therefore, it is subdivided into two (2) subzones at the 2,500-foot elevation.

- D - This zone typically occurs on the windward side of the islands and has a minimum rainfall of 60 inches at sea level. The maximum rainfall averages can exceed 200 inches. This zone is subdivided into three (3) subzones with no distinct characteristics. The authors chose the upper limit of the lower subzone to represent the highest level of present and probable future agriculture development (circa 1940). The upper (highest) subzone is characterized by having the highest rainfall and is above the 4,000- to 5,000-foot elevation.

  Sugar cane was grown in suitable areas without irrigation. There are truck crops grown in these zones, but the wetter conditions increase the impact of insects and diseases.

- E - The zone covers the upper elevation of the islands, and is found only on Haleakalā, Mauna Kea, Mauna Loa, and Hualālai. Only a small part of this zone is suitable for agriculture, as it generally lacks deep soils and the temperature is cooler (below 60 degrees Fahrenheit). The forest reserve and other national parks occupy most of this zone.

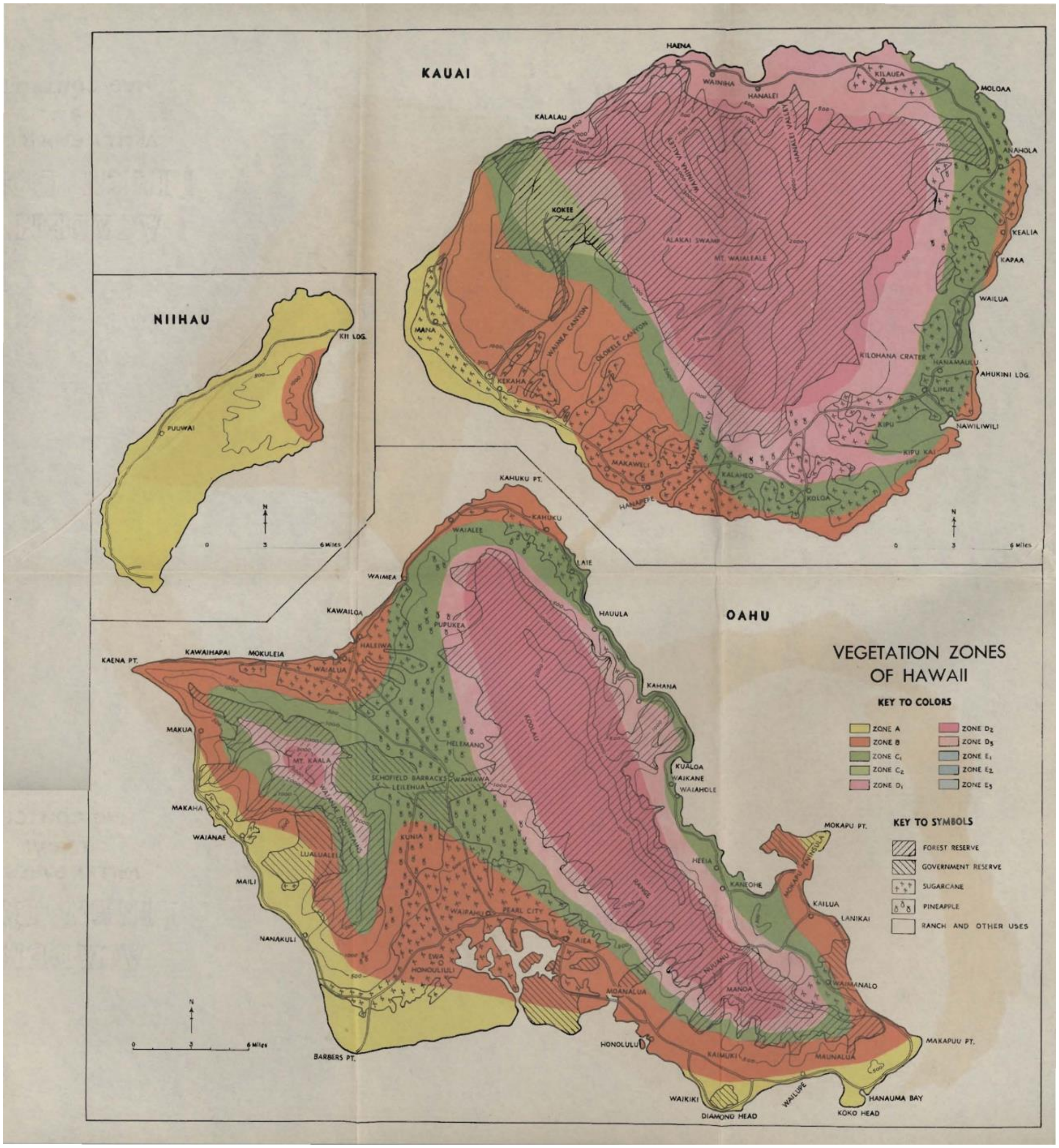

Exhibit 33 - Ripperton and Hosaka - O‘ahu, Kaua‘i and Ni‘ihau

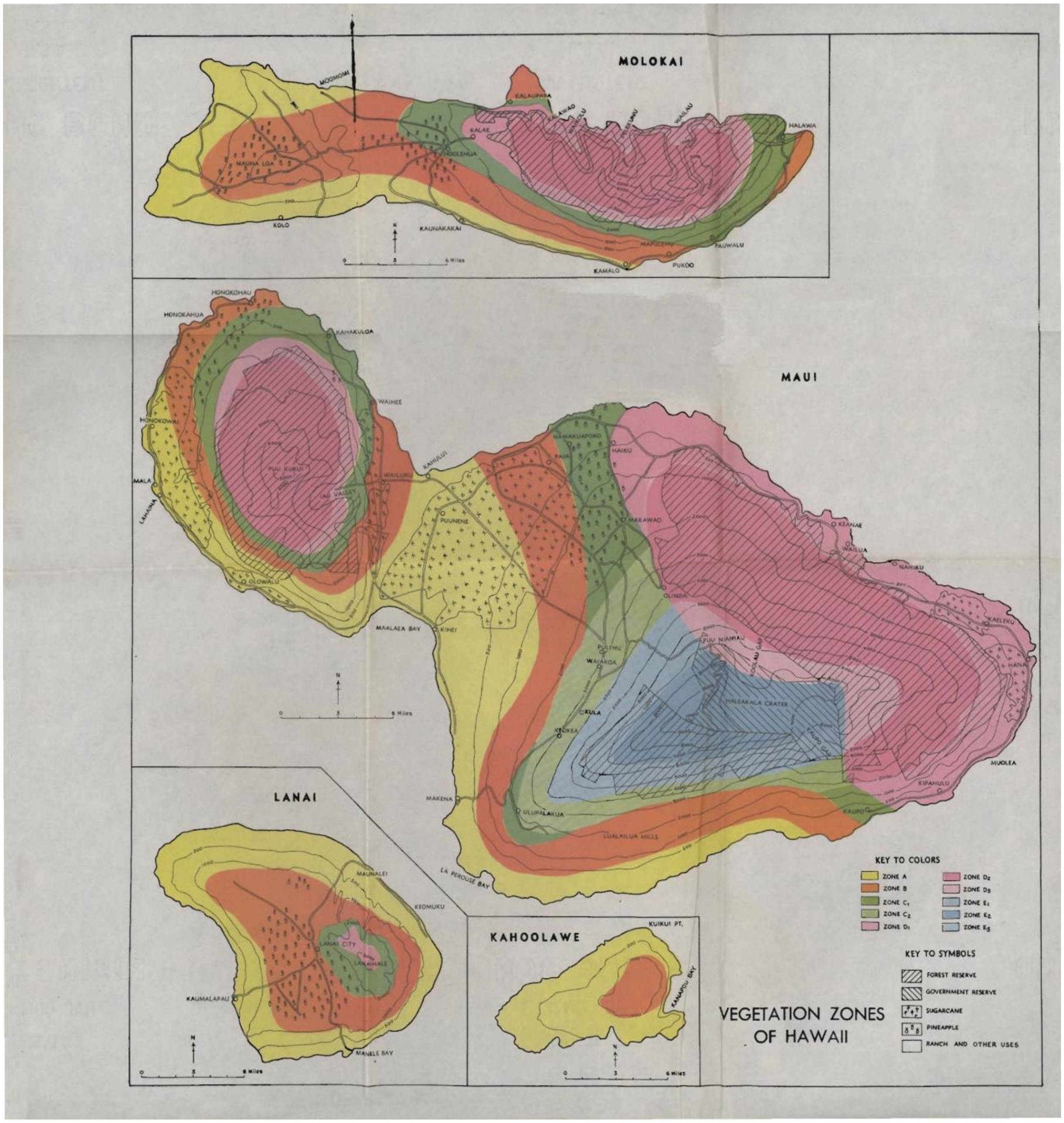

Exhibit 34 - Ripperton and Hosaka - Maui County

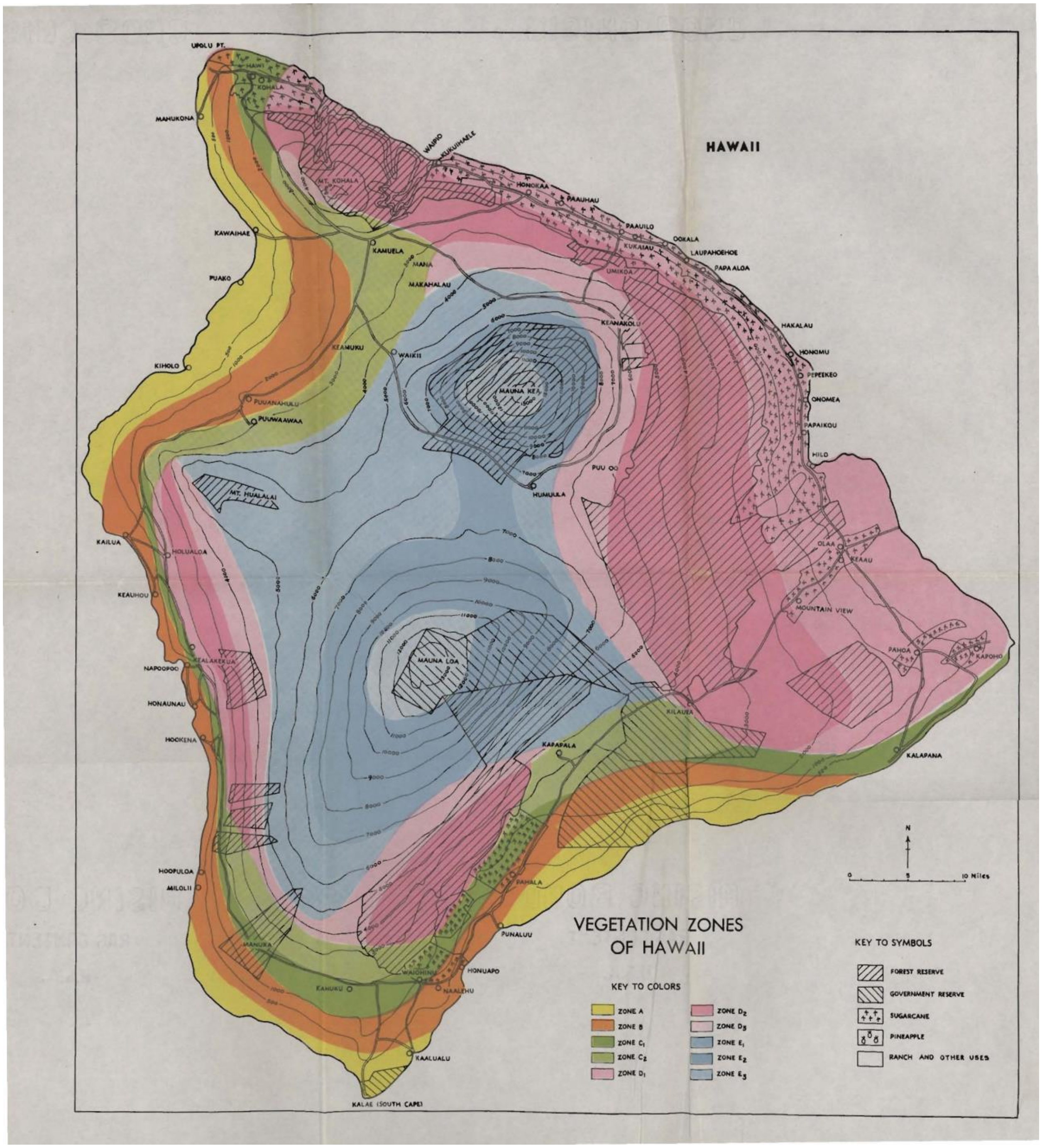

Exhibit 35 - Ripperton and Hosaka – Hawai'i County

In 1956, the **Hawai'i Irrigation Authority** completed an in-depth study of irrigation requirements and resources for the Waimānalo Irrigation System.[29] The study cites flow records (1924-1941) that show extreme drought flow from upper Maunawili Valley is 1.3 MGD, compared to the "dependable low flow"[30], estimated at 1.8 MGD. To provide an accurate estimate of crop water requirements, the Authority selected 14 farms that had variations in soil and rainfall conditions; diversification of crops; and different methods of cultivation and irrigation.

The analysis of the 14 farms indicated that water demand ranged from a low of 0.016 acre-inch per acre per month (15 gpd/acre) to 1.37 acre-inch per acre per month (1,240 gpd/acre). The mean was 0.64 acre-inch per acre per month (579 gpd/acre). This was based on water meter data at the farms and does not include on-farm irrigation system losses. The 14-farm analysis concluded that the best method to analyze water demand for the farm area was to use the data collected from farms spread out within the Waimānalo system. It provided representative water use that is reliable for the range of farms, climates, and soil types within the farming area.

The study concluded that three (3) water use numbers are needed to provide an estimate of water requirements for the farms in the area: 1) mean annual water, 2) maximum monthly water, and 3) maximum seasonal water. The definitions of the water requirements are provided below.

- Mean annual water requirement: To estimate pumping costs and revenues for economic studies and water rate establishment.
- Maximum monthly water requirement: To estimate irrigation requirements and determine the adequacy of the water resource. To a lesser degree, the maximum daily requirement also needs to be considered in establishing irrigation system requirements.
- Maximum seasonal water requirement: To determine the total water required, adequacy of available water resources over the "dry" summer period, and, more importantly, storage requirements for the system.

[29] Hawai'i Irrigation Authority, *Irrigation Requirements and Available Water Resources, Waimānalo Irrigation System,* Territory of Hawai'i, 1956.

[30] Dependable Low Flow - defined as the lowest flow which occurs in four out of five years, except for an occasional isolated day or two.

Based on the 14-farm analysis, estimated water requirements for the Waimānalo Farm area are shown in Tables 121 to 123. The 15.2 acre-inch per acre per year computes to 1,131 gpd/acre. The 2.60 acre-inch per acre per month during the "dry season" computes to 2,277 gpd/acre.

Table 121
Estimated Irrigation Water Requirements - Average Year

	Water Demand Per Acre		Annual Total for Irrigation System
	Acre-Inches	**Gallons**	**Gallons**
Farm Diversion Requirements[1]	15.2	413,000	227,000,000
Diversion Requirements at Source[2]	43.4	1,180,000	649,000,000

Note: 1. The diversion requirements assume 50 percent of the farm area is irrigated at any given time. The diversion requirement is the water delivered to the diversion gates at farm.
2. Assumes 65 percent distribution system losses.

Table 122
Estimated Irrigation Water Requirements - Maximum Month
(based on no effective rainfall)

	Water Demand Per Acre		Maximum Month Total
	Acre-Inches	**Gallons**	**Gallons**
Farm Diversion Requirements(1)	3.0	81,000	53,500,000
Diversion Requirements at Source(2)	6.0	163,000	107,000,000

Note: 1. The diversion requirements assume 60 percent of the farm area is irrigated at any given time.
2. Assumes 50 percent distribution system losses.

Table 123
Estimated Irrigation Water Requirements - Maximum Season
(June to October)*

	Water Demand Monthly Total Per Acre		Maximum Seasonal Total
	Acre-Inches	**Gallons**	**Gallons**
Farm Diversion Requirements(1)			
2 months	3.00	82,000	98,600,000
1 month	2.60	71,000	42,700,000
2 months	2.20	60,000	72,200,000
Total	**----**	**----**	**213,500**
Mean per month	2.60	71,000	42,700
Diversion Requirements at Source(2)			
2 months	6.67	181,000	219,000
1 month	5.78	157,000	94,900
2 months	4.89	133,000	160,600
Total	**----**	**----**	**474,500**
Mean per month	5.78	157,000	95,000

Note: 1. The diversion requirements assume 55 percent of the farm area is irrigated at any given time.
2. Assumes 55 percent distribution system losses.
3. This assumes that there is a minimum of 6 inches of rainfall during the five (5)-month "dry" season.

In 1959, **Hawai'i Water Authority** statistics show agricultural water demand for Waimānalo Irrigation System was 161 million gallons per year, with a revenue of $37,133. However, maintenance and operational costs for this system showed a deficit of $21,869, even with cost-reduction measures in place. The system served 814 acres, 119 of which were used by the University of Hawai'i experimental farm.

The summary in the 1959 Annual Report[31] listed the following important findings in the Water Resources report.

- "*Variety of Problems. The rainfall of the state is relatively high, averaging better than 70 inches annually. However, development of Hawai'i's water resources is both difficult and costly due to extreme variations in distribution of rainfall, wide differences in monthly, seasonal, and annual rainfalls, recurring droughts, lack of suitable impounding reservoir sites, problems of salt water intrusion in basal ground-water supplies, and mountainous topography*."

- "*Adequacy of Water Resources. Water problems in Hawai'i are not problems of inadequacy or impending inadequacy of available water resources. With proper planning and management, there will always be adequate water resources in the State — at a price. The problem is to supply water in the quantity needed, when needed, and where needed for municipal, military, irrigation, and industrial uses.*"

- "*Water Usage. Water utilization in the state in 1957 amounts to approximately 700 billion gallons, of which 60 percent was derived from surface-water sources and the balance from subterranean supplies. Principal categories of water use were domestic and municipal, 5 percent; irrigation, 74 percent; and industry, 19 percent, of which three-fourths was used for development of hydro-electric power. Per capita use in 1957 was approximately 3,440 gallons per day, a figure over double the average of the mainland United States.*"

- "*Changing Conditions. The water sources of Hawai'i have been extensively developed during the past eighty years by individuals, private business, and governmental agencies to meet various needs as they arose. Changing economy in the state and greater competition for undeveloped or partially developed water sources will impose increasing problems in the further exploitation of water*

[31] This was the last report from the Hawai'i Water Authority, as the functions of the Authority was transferred to the Hawai'i Department of Land and Natural Resources.

> *resources. These problems can best be met through proper long-range planning, coordinated efforts, and sound management."*

The Authority summarized water duty by crop, stating that irrigation varies greatly due to climate, soil conditions, method of application, and other factors, but mainly due to differences in crop requirements. For sugar cane, the water requirement is between eight (8) to nine (9) acre-feet per acre per year. However, if more water is available, demand could shoot as high as ten (10) or more acre-feet per acre per year. The eight (8) acre-feet per acre per year converts to approximately 7,140 gpd/acre, and nine (9) acre-feet per acre per year converts to 8,035 gpd/acre.

Heavy water-use crops are those grown in paddies or by flood irrigation, such as taro, rice, watercress, and lotus roots. For high-quality (prime) watercress, water demand is approximately three (3) acre-feet per acre per day, or about one (1) million gpd/acre. Pineapple cultivation has a water demand of approximately six (6) acre-inches per year. The variety of diversified agriculture crops, as well as the effects of climate and soil, creates a range of water demand from one and one-half (1 1/2) acre-feet per year per acre (1,340 gpd/acre) to three (3) acre-feet per acre per year (2,680 gpd/acre), with some crops exceeding five (5) acre-feet per acre per year (4,463 gpd/acre).

The 1959 Water Resources report also looked at the following water conservation measures:

- For surface water development
    - Seepage reduction,
    - Soil conservation practices,
    - Reduction of surface evaporation, and
    - Waterproofing catchment areas;

- For ground water development
    - Reducing leakage from the Ghyben-Herzberg lens,
    - Recharging, and
    - Artesian well sealing;

- Other conservation measures
    - Reuse of industrial and irrigation waters,
    - Use of treated sewage,
    - Reforestation,
    - Cloud seeding, and
    - Saline conversion.

The final recommendation was:

> *It is recommended that in order to encourage the expansion of diversified farming in the interest of the State's economy, the Legislature give consideration to some form of subsidization for irrigation projects where financial help is needed. Existing statutes require repayment of principal and interest for capital costs of construction which, in some instances, may make the cost of irrigation water too high for economic farming.*

In the **late 1990s**, the **State of Hawai'i, Department of Agriculture** and its partners developed watershed plans for several irrigation systems in the state. The Lower Hāmākua Ditch (LHD) Watershed Plan and Final Environmental Impact Statement computed water demand by crop, which was based on pan evapotranspiration results. Table 124 presents the various crop irrigation requirements for crops grown below the 500-foot elevation and above the 500-foot elevation in the Kukuihaele to Pa'auilo area. The 80 percent chance of rainfall represents the rainfall expected on average during the driest and second driest years of a ten-year group. The 50 percent rainfall represents the median annual rainfall, or the average rainfall condition. The average daily irrigation requirement (Table 125) is based on the peak irrigation month that typically corresponds to the month with the highest evapotranspiration rate and lowest rainfall.

Table 124
Summary of Average Daily Crop Water Demand
Lower Hāmākua Ditch, Kukuihaele to Pa'auilo
(gpd/acre)

		Crop Water Demand Below 500 feet			**Crop Water Demand Above 500 feet**	
Rainfall		50%	80%		50%	80%
Banana		2,211	3,236		1,425	1,964
Coffee		1,471	2,079		852	1,296
Papaya		1,471	2,079		852	1,296
Macadamia nut		1,140	1,578		562	992
Foliage/flowers		1,808	2,655		1,140	1,600
Truck crops		1,140	1,578		562	992
Reference Crop		1,500	2,100		900	1,350
Effective Daily Rainfall (inches)		*0.11*	*0.09*		*0.13*	*0.10*
(gpd/acre)		2,986	2,443		3,530	2,715

In 2008, **Ali Fares, Ph.D.** prepared the *Irrigation Water Requirement Estimation Decision Support System (IWREDSS) to Estimate Crop Irrigation Requirements for Consumptive Use Permitting in Hawai'i*, for the State of Hawai'i, Department of Land and Natural Resources, Commission of Water Resource Management. IWREDSS was updated in 2013, when Version 2.0 was released. IWREDSS is an Arc-GIS-based numerical simulation model developed to help estimate crop irrigation requirements for consumptive use permitting in Hawai'i. The model estimates irrigation requirements and other water budget components, including net irrigation water requirements, gross irrigation water requirements, water duty, gross rain, net rain, effective rain, runoff, canopy interception, potential evapotranspiration, reference evapotranspiration, and drainage.

Table 125
Summary of Average Daily Crop Water Demand
Peak Month
Lower Hāmākua Ditch, Kukuihaele To Pa'auilo
(gpd/acre)

	Crop Water Demand Below 500 feet		**Crop Water Demand Above 500 feet**	
Rainfall	50%	80%	50%	80%
Banana	6,133	6,733	4,733	5,467
Coffee	4,600	5,167	3,367	4,067
Papaya	4,600	5,167	3,367	4,067
Macadamia nut	3,833	4,367	2,733	3,367
Foliage/flowers	5,367	5,933	4,067	4,767
Truck crops	3,833	4,367	2,733	3,367
Reference Crop	4,700	5,300	3,500	4,200
Effective Peak Month Rainfall (inches)	*1.67*	*1.25*	*2.21*	*1.66*

CWRM uses the IWREDSS software program to determine the water allocation for agriculture irrigation demand for an applicant (farmer). IWREDSS computes the irrigation demand based on the farm's location, crop type, acreage, and an 80 percent rainfall frequency (or an average drought rate of one in five years). Currently, IWREDSS can compute the irrigation requirements for approximately 50 crops.

The annual amount used by the applicant is computed on a moving annual total from the date of inquiry, and the applicant cannot exceed the moving annual total at any time. Therefore, if rainfall is less than the 80 percent rainfall frequency or the drought periods are longer than assumed, the applicant can easily exceed the annual allocation or will need to reduce the amount of acreage farmed to stay within the moving annual water allocation.

In 2011, **Mink and Yuen** performed a water study for Kula, Maui. The report computed the estimated water budget for the upper and lower Kula agriculture production areas. To perform the water budget analysis, the study analyzed the 30-year rainfall record of the Kula Branch Station. The study concluded that the 50 percent rainfall frequency was the median (normal); 80 percent rainfall frequency was equivalent to typical drought conditions, occurring at an average rate of once every five (5) years; and 90 percent rainfall frequency was equivalent to extreme droughts, averaging once every 10 years. Rainfall records indicate that during drought conditions, rainfall amounts range from zero (0) to less than one (1) inch. Water budget analysis results are shown on Table 126 for the three conditions: normal, drought, and severe drought.

Table 126
Average Daily Irrigation Water Requirements
Kula Farms

	Upper Kula Farms			**Lower Kula Farms**		
	Median Rainfall	**Drought**	**Severe Drought**	**Median Rainfall**	**Drought**	**Severe Drought**
Average Daily Water Requirement (gpd/acre)	2,577	3,029	3,221	3,889	4,371	4,577
Peak Daily Water Requirement (gpd/acre)	4,093	4,294	4,416	5,711	5,930	6,063

In 2014, **Giambelluca, T.W., et.al.** published the *Evapotranspiration of Hawai'i*. The 2014 Evapotranspiration of Hawai'i project was conducted under an agreement between the State of Hawai'i Commission on Water Resource Management and the U.S. Army Corps of Engineers, Honolulu District under Section 22 of the Water Resources Development Act of 1974. The development of the evapotranspiration, solar, and climate websites, including their interactive map tools, was supported by National Science Foundation Hawai'i EPSCoR grant no. EPS-0903833. The results are found on the website: http://evapotranspiration.geography.hawaii.edu/.

6.3 2014 INFORMATION GATHERING

To determine water demand for agriculture, surveys and interviews were undertaken with farmers throughout the state. Actual water use and water concerns were collected using two different methods: a formal survey of farmers in agricultural areas and informal interviews with farmers and system managers.

6.3.1 METHODOLOGY

During the formal survey, individual farmers and ranchers were asked specific questions about water use. Questions are shown in Appendix C. Research was conducted on 113 farms in the Waimānalo, Kahuku, Mililani, Kula, Pāhoa, Pana'ewa, Hāmākua, East Kaua'i, and Moloka'i agriculture parks. Additional water demand information was gathered from the Kunia agricultural area. The data was collected by professional field staff visiting each farm between April 10 and May 26, 2014. During the interviews, farmers and field staff defined the typical "wet season" to be January and February, and the typical "dry season" to be July and August.

In many cases, farmers did not know the precise number of gallons used on their farm. However, in most of these cases, farmers shared their monthly water bills, and, with the help of the water supply agencies on each island, the gallon usage by farm was computed. Due to variations in water usage and planted acreages, interviewers confirmed the information with the farmers with follow-up meetings or telephone conversations.

The information-gathering process involved informal discussions on water demand and irrigation systems with stakeholders, farmers, and ranchers. These informal discussions were held to collect additional information, provide quality control on the survey information, and to supplement information gathered from stakeholders.

6.3.2 DISCUSSION OF THE FORMAL SURVEY RESULTS

A summary of the formal survey data for average water usage by farms and by island is shown on Table 127. The maximum water requirement for the dry and wet seasons on the island of Hawai'i is influenced by the data reported from the Keāhole agriculture lots, which has average annual rainfall of 18 inches.

The dry season monthly averages range from 161,500 to 442,800 gallons per acre for most of the state, excluding Kaua'i. This translates to a daily water demand ranging from approximately 5,200 to 14,500 gpd/acre. Note that some crops in different areas exceed 1 million gallons per month per acre, which is more than 32,000 gpd/acre. In addition, the on-farm irrigation type illustrates variations in water demand, as shown in Table 128.

Table 127
Monthly Average Farm Water Demand
(based on survey responses)

Location	Average Wet Season (gpd/acre)	Average Dry Season (gpd/acre)	Range Wet Season (gpd/acre)		Range Dry Season (gpd/acre)	
			Min	Max	Min	Max
Hawai'i	4,164	5,298	0	87,432	0	87,432
Maui	3,304	10,139	0	8,197	295	24,792
Moloka'i	6,237	14,520	63	32,787	63	98,361
O'ahu	3,840	7,183	0	52,459	2	65,574
Kaua'i	87	905	0	557	1	3,541

Table 128
Average Monthly Water Demand by Irrigation Type
(based on survey responses)

Irrigation Method	Number of Farms	Wet Season (gpd/acre)	Dry Season (gpd/acre)
Drips	49	3,680	9,260
Sprinklers	29	5,910	7,578
Water Hose	12	4,507	5,367
Ponds	1	59	5
Aquaculture	1	4,662	4,662

Table 129 presents the following information for each agricultural area included in the survey.

- The range of water demand during the dry season and estimated annual average water use.
- Farm water demand computed based on actual cultivated area, not the total parcel area.
- Average annual rainfall.
- The vegetation zone based on the Ripperton and Hosaka maps.

Table 129
Surveyed Farm Water Usage and Rainfall

Location	Average Dry Season Water Usage* (gpd/acre)		Estimated Average Annual Water Usage* (gpd/acre)		Average Annual Rainfall (inch)**	Vegetation Zone***
	Low	High	Low	High		
Pāhoa	0	5,059	0	4,662	134	D1
Pana'ewa	0	13,230	0	6,809	129 - 140	D1
Keāhole	725	87,432	725	87,432	18	A
Kula	295	24,792	148	14,875	16 - 27	B
Moloka'i	63	98,361	63	65,674	17 - 21	A & B
Mililani	118	65,574	59	59,016	26 - 37	B
Waimānalo	2	8,431	2	7,561	51 - 67	C1 & D1
Kahuku	173	39,742	173	19,871	43 - 52	B - C1
Kaua'i	1	3,541	1	1,770	45 - 52	C1

NOTES: * Farm acreage is based on planted area.
** Giambelluca, T.W., et al., *"Online Rainfall Atlas of Hawai'i"*
*** Ripperton and Hosaka, "*Vegetation Zones of Hawai'i*"

Based on the farms surveyed, average farm water demand for the dry season (lower rainfall period) is 214,000 gallons per acre per month, and the estimated annual average is 170,000 gallons per acre per month. This computes to a daily water demand of about 7,020 gpd/acre for the dry season and 5,560 gpd/acre on an annual basis, or 1.8 inch-acre and 1.4 inch-acre per week, respectively. Water demand from other farms located on leeward portions of the islands average 8,425 gpd/acre for dry months, with an annual average of 7,344 gpd/acre.

6.4 RECOMMENDED WATER DEMAND

6.4.1 2004 AWUDP WATER DEMAND

The 2004 AWUDP determined that analysis for the recommended water demand shall be based on metered irrigation water demand data. This methodology was selected for its reflection of actual growing methods. For certain commercial crops, a growing cycle may include several harvesting cycles during a calendar year. Portions of the land may be rotated out of cultivation and left unirrigated for a short period of time as part of routine farming activities.

To account for such practices, the 2004 AWUDP water demand was based on metered irrigation water data. The Lālāmilo section of the Waimea (Upper Hāmākua) Irrigation System was selected for this analysis. The Lālāmilo area has been cultivated for diversified crops by dedicated, full-time farmers for many years.

Based on eight (8) years of records, an average of 3,400 gpd/acre (rounded from 3,461 gpd/acre) was determined to be the application rate of irrigation water use for diversified crop farming in Lālāmilo. Therefore, the 2004 AWUDP concluded that 3,400 gpd/acre is the best available estimate for diversified agriculture water demand. This recommended water demand rate is tempered by an acceptable level of conservation practices, including the Hawaiʻi Board of Agriculture administrative rules governing irrigation systems' conservation practices.

6.4.2 CURRENT WATER DEMAND

This AWUDP update revisits the recommended water demand estimate for diversified agriculture. The analysis considers metered irrigation water data from farming areas throughout the state and historic water demand. The analysis of the water demand found the following average water demand rates.

- The 2014 farm survey data identified an average annual farm water demand of 4,022 gpd/acre at the water meter. This demand rate is based on the cultivated land area and metered irrigation water data at farms that practice good farming principles, such as crop rotation. Crop rotation allows the land to rest (remain fallow) between crops, and in the surveyed farms the average planted area was approximately 48 percent of the cultivatable land and 52 percent remained fallow (with no cover crop).

- The Kunia, Oʻahu, farms reported that the water demand for 2012 and 2013 was an average of 4,034 gpd/acre at the water meter. This demand rate is based on the cultivated land area, as well as metered irrigation water data at farms that implemented crop rotation and use no cover crop.

- The historical data on diversified agricultural water demand, not including sugar cane cultivation, provided a computed average of 3,781 gpd/acre. The farming practices considered in this evaluation also implemented 50 percent planted area with no cover crop on the unplanted area (crop rotation).

The average water demand rate of these three (3) data sets is 3,946 gpd/day. Therefore, it is recommended that the planning-level water demand rate is 3,900 gpd/day at the farm meter, based on 50 percent field rotation (annually) and no cover crop. Allowing lands to remain fallow for part of the year is considered a good farming practice. Conversely, if farmers do not fallow the fields, they are likely to rotate the plantings with other crops. In similar farming scenarios, if little or no crop rotation (100 percent of the farmable land is planted) occurs and irrigation water is required for 100 percent of the fields annually, then the average water demand is expected to double, and the associated water demand planning estimate is 7,800 gpd/acre.

To provide an average water demand rate for diversified agriculture, an effort was made to exclude outlier data. In calculating the average water demand of 3,946 gpd/day, wet crops such as taro and aquaculture were excluded from the average computations. The remainder of the data used in the calculations cover a wide range of farming scenarios, including both dry (higher water demand rate) and wet (lower water demand rate) growing regions, to arrive at the average water demand rate.

The aforementioned water demand is based on typical farming conditions, averaged on an annual basis. However, for planning purposes, it should be noted that for dry periods throughout the year or during drought conditions, water demand is higher to account for the lack of rainfall. During the dry months, the same farms reported the following water demand rates.

- The 2014 farm survey data identified an average dry-month farm water demand of 7,775 gpd/acre at the water meter. This demand rate is based on the cultivated land area and dry-month metered irrigation water data at farms that implement an average of 48 percent crop rotation and use no cover crop.

- The Kunia, O'ahu, farms had an average dry-month water demand of 8,556 gpd/acre for 2012 and 2013. This demand rate is based on the cultivated land area and dry-month metered irrigation water data at farms that utilize good farming practices, implement crop rotation, and use no cover crop.

The average dry-month/drought water demand from the two (2) data sets computed to 8,166 gpd/acre, as the farmer is required to significantly increase water to the crops to maintain an economic level of production. Therefore, it is recommended that a planning-level water demand of 8,100 gpd/day be considered for dry-month/drought conditions, based on a 50 percent field rotation (annually), at the farm meter. In similar farming scenarios, if the majority or all of the lands are planted (little or no crop rotation), then the irrigation water is required for 100 percent of the fields annually, the average water demand during dry months/drought conditions is expected to double, and the associated planning estimate is 16,200 gpd/acre. This planning average water demand factor for dry/drought conditions is provided with consideration of drought planning, potential climate change variations, and for growing regions on the leeward side.

Table 130 presents multiple water demand planning rates to represent generalized farming practices and rainfall conditions that are commonly used or encountered throughout the state. The table includes rates for dry/drought conditions; likewise, the Plan user should recognize that wet regions are likely to use less water for their crops.

Users of these demand rates should note that water use varies by many factors, and a one-size-fits-all approach should not be applied for every agricultural endeavor. Chapter 7 delves into these factors in more detail. Furthermore, if a specific area (site) is being developed or used for agriculture, a site-specific study should be performed to determine the water demand rate and water storage, as well as to develop potential water management techniques.

Users of these water demand planning rates may refer to Table 130 to estimate the gallons of water that may be needed for a given area. For example, if the farmer allows the land to remain unplanted (non-irrigated) 50 percent of the time, the annual average water demand rate for planning purposes is 3,900 gpd/acre. If the land is planted and irrigated throughout the year, the annual average water demand for planning purposes is 7,800 gpd/acre. For irrigated pastures, the water demand rate is estimated to be 8,000 gpd/acre or higher and will be dependent on location, soil type, and climatic factors.

These water demand rates are for statewide planning for agricultural water demand. If a specific site is being studied, a site-specific water demand analysis should be completed. For aquaculture and wetland taro, the water demand rate will be dependent on the crop, technologies used, location, and farmer preference. Non-irrigation uses, such as pest control, will be dependent on the farming practices, crop, and pest control measures.

The water demand rates provided in this document are for farming and agricultural uses only, and do not apply to "gentleman farms." The estimated rates reflect water demand at the farm meter for agricultural planning considerations, but do not reflect water source planning. To estimate a planning water demand rate at the source, a distribution system loss factor should be used. In the past, the distribution loss factor was based on an estimated distribution system loss of 50 percent or 65 percent,[32] and 50 percent in the 2004 AWUDP. If a 50 percent distribution loss was assumed and applied to the agricultural water demand rate of 3,900 gpd/acre at the farm meter, the corresponding source production (flow) rate estimate would be 7,800 gpd/acre. To better estimate source production requirements, further studies of water losses for the specific distribution and storage components should be performed for each agricultural water system.

Table 130
Agricultural Water Demand Planning Rates
(at the farm meter)

Description	Water Demand (gpd/acre)
Diversified agriculture (for usable acreage that is 50 percent planted)(average condition) (e.g. leafy vegetables and truck crops)	3,900
Diversified agriculture (for usable acreage that is 100 percent planted) (e.g. nursery, feed, and forage crops)	7,800
Diversified agriculture (for usable acreage that is 50 percent planted) under drought conditions or in dry areas	8,100
Diversified agriculture (for usable acreage that is 100 percent planted) under drought conditions or in dry areas	16,200
Irrigated pastures dependent on grass varietal, soil, and climatic conditions (for usable acreage that is 100 percent planted)	8,000
Aquaculture, taro, and other wet crops	Dependent on crop and location

[32] The Hawai'i Irrigation Authority used a range from 50 to 65 percent distribution loss in the computation of source planning for Waimānalo, 1956.

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CHAPTER 7
FACTORS AFFECTING AGRICULTURAL WATER DEMAND

Agriculture looks different today – our farmers are using GPS and you can monitor your irrigation systems over the internet.
Debbie Stabenow

Agricultural water demand for crops is determined by factors such as leaf coverage, soil type, and climate. However, government policies, market forces, and environmental factors also impact crop demand. The quantitative impacts from these factors are difficult to determine, and the significance of the impact is typically proportional to the intensity of the factor. Other factors impact water availability, such as government policies, climate, and development cost.

As some of the factors affect both water demand and water availability, this chapter is organized by categories. Section 7.1 discusses water use by crop type. Section 7.2 discusses increase in market demand, which relates to water demand, and section 7.3 discusses environmental factors. Section 7.4 discusses how government policies impact agriculture water availability and demand, and section 7.5 summarizes legal rulings by the CWRM and/or the State of Hawai'i courts, which impact water rights, water availability, and management. Section 7.6 discusses other considerations for water demand during farm planning and design.

7.1 WATER USE FOR CROP TYPE

The survey shows a wide range of water demand due to climatic conditions, soil characteristics, and farmer preference. Table 131 presents a summary of statewide water demand by crop type and provides a comparison to the HDOA 2004 AWUDP water demand guidelines. The maximum water demand is important, as it provides an indication of water demand during the dry season. These maximum water demand rates may be useful in developing water demand for issues such as climate change, drought mitigation, and sustainability.

Similarly, the cultivation of wetland taro shows a high variability of water demand. A USGS report[33] on taro cultivation measured water temperature and water flow for 19 complexes on the islands of Kaua'i, O'ahu, Maui, and Hawai'i. The water measurements were taken during continuous flooding periods on mature crops. The wetland taro water demand by county is summarized in Table 132.

Table 131
Comparison between 2004 AWUDP
Water Use Guidelines and 2014 Farm Survey Results
(gpd/acre)

Commodity	2004 AWUDP	2014 Farm Survey		
		Average	Min.	Max.
Potted plants	6,000	21,411	94	87,432
Orchids	3,700	1,892	393	3,356
Vegetables	4,050-6,700	3,923	148	12,545
Taro dry	4,000-8,000	10,631	10,246	11,017
Field crops (including grains)	6,700-7,700	3,538	2	11,340
Banana	n/a	4,570	557	19,871
Anthuriums	n/a	1,869	0	6,809
Trees and fruit trees	n/a	3,039	9	15,747

n/a - not available

[33] Gingerich, S.B., et. al., *Water Use in Wetland Kalo Cultivation in Hawai'i*, U.S. Geological Survey Open-File Report 2007-1157, 2007.

Table 132
Summary of Water Use Calculated for Lo'i Complexes
(gallons/acre/day)

County	Average	Average Windward	Average Leeward
Kaua'i	120,000	97,000	260,000
O'ahu	310,000	380,000	44,000
Maui	230,000	230,000	Not available
Hawai'i	710,000	710,000	Not available
All measurements	260,000	270,000	150,000

Reference: Gingerich, S.B., et. al., *Water Use in Wetland Kalo Cultivation in Hawai'i*, U.S. Geological Survey Open-File Report 2007-1157, 2007.

7.2 INCREASED MARKET DEMAND

During the study, there were agricultural opportunities to increase production in several areas based on the consumer market. Two (2) of these opportunities may have a significant impact on water demand and are steps toward fulfilling the State's policy of self-sufficiency.

The first opportunity is the growing interest in the cultivation of wetland taro, which will necessitate an increase in water demand, as taro is one of the highest water demand crops per acre. Another opportunity is the expanding market for grass-fed beef and locally finished meats. This opportunity also increases the need for grass pastureland, which requires water irrigation at approximately two (2) inches per acre per week, depending on climate, soil, and grass variety. Note that a unit of cattle will need to be sustained on grass for approximately 18 months, thus requiring stable irrigation to provide economic value for the rancher and to maintain the "grass-fed" label.

7.3 ENVIRONMENTAL FACTORS

Environmental factors, such as drought and climate change, impact agricultural water demand. Average water demand is based on a crop receiving typical average annual rainfall. As drought conditions and climate change alter rainfall events, there will ultimately be extended periods of no rainfall. During these zero (0) rainfall events, irrigation water must supply the total water need for the crop. In some areas, this water demand may exceed 8,000 gpd/acre. Rainfall frequency also impacts the water availability to the crop and aquifer recharge.

7.3.1 RAINFALL FREQUENCY

Irrigation cycles are dependent on rainfall events, but daily rainfall can vary in frequency and intensity, and is not indicative of the average monthly data reports. For example, two (2) rainfall event charts are presented for the Kunia Substation rainfall gauge on O'ahu. The first chart, in Exhibit 36, presents the rainfall events of January 2011, and the second chart, in Exhibit 37, presents the rainfall events of January 2014. The monthly rainfall totals are about the same, as January 2011 had a total of 3.3 inches, and January 2014 had a total of 3.59 inches. This rainfall amount is equivalent to approximately 3,000 gpd/acre if distributed uniformly over the month.

In this example, although the total monthly rainfall is similar, 3.3 versus 3.59 inches, the number of "dry days" (less than 0.1 inches of rainfall[34]) in January 2011 is 26, compared to 18 in January 2014. Therefore, to provide consistent water to crops, the farmer would need to irrigate approximately 12 times in January 2011, compared to approximately seven (7) times in January 2014. For all crops, evenly distributed water supply (rainfall or irrigation) is conducive to optimal growth. For example, consider a crop such as lettuce:

> "*Fluctuations in soil moisture, especially during the later stages of development, are severely detrimental to optimal growth. Too much water during this period, along with high temperatures, may result in loose, puffy heads in heading types of lettuce. Too dry conditions during this period may induce premature bolting* (forming flowers and seeds)[35]."

[34] Also, note that light rainfall events (less than 0.1 inches) are not effective, as the rain evaporates prior to being absorbed into the soil, thus rendering it unusable by the plant.
[35] University of Hawai'i, College of Tropical Agriculture and Human Resources, Farmer's Bookshelf - Lettuce, http://www.ctahr.hawaii.edu/fb/lettuce2/lettuce2.htm#Fertilizer.

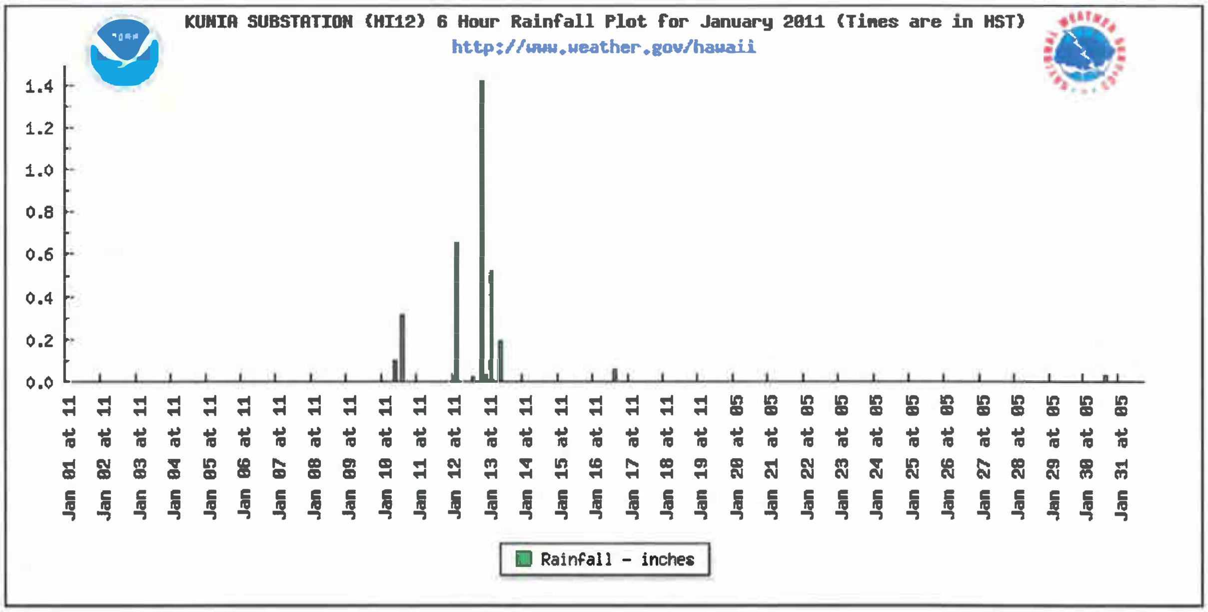

Exhibit 36. Rainfall Plot for January 2011, Kunia Substation (HI12), estimated rainfall total is 3.3 inches.

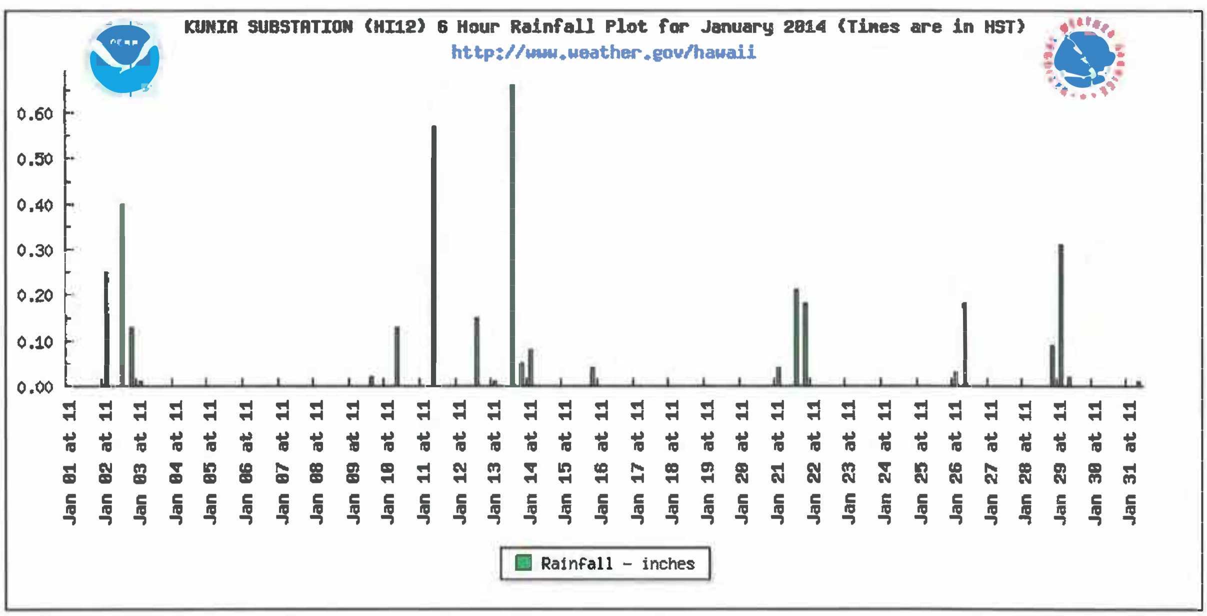

Exhibit 37. Rainfall Plot for January 2014, Kunia Substation (HI12), estimated rainfall total is 3.59 inches.

7.3.2 DROUGHTS

Certain areas within the state have endured droughts with disastrous impacts to agricultural production. If agriculture is to survive, the availability of agricultural commodities in the market needs to be dependable. In addition, if the State's policies continue to trend toward sustainability and food security, the importance of available water during drought conditions is even more critical. A recent paper by Howitt, et.al., reported the economic impact of the 2015 drought in California, which had a direct cost to the California economy of approximately $1.8 billion and indirect economic impact of half that amount. Crop revenue losses were approximately 2.6 percent of total crop revenue, and about 45 percent of the land had turned idle or fallow.

In Hawai'i, drought impacts can be seen in the South Kohala and Kula regions of the state. In the South Kohala region of Hawai'i Island, a long drought between 2007 and 2008 reduced agricultural exports from this area. The number of cattle units shipped out of Kawaihae Harbor dropped from an average of 304 prior to 2007 to an average of 43 after 2008. In 2008, the number of cattle units exported through Kawaihae Harbor was zero. Similarly, the number of agricultural shipping containers[36] dropped from an average of 842 prior to 2007 to an average of 594 after 2008. The global recession of 2008 probably compounded the problem.

The impact on droughts on the Lower Kula agricultural area was documented in the 2011 *Kula Stormwater Reclamation Study*[37]. The lower Kula agricultural area generated an estimated net revenue of $2.1 million in 2003 from 215 farms on approximately 570 acres. The drought between 1998 and 1999 created a water restriction of 10 percent for a period of 20 months. Table 133 presents the estimated decrease in agricultural production due to water restrictions.

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[36] Agricultural containers are represented as twenty-foot container units (TEU) for statistical purposes.

[37] Mink and Yuen, Inc. & Associates, *Kula Stormwater Reclamation Study, Task 1, Existing Conditions Report*, Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

Table 133
Estimated Agricultural Production Impacts Due To Ten Percent (10%) Water Restriction

Crop	Decrease Crops Planted	Decrease Acres Harvested	Decrease Pounds Harvested
Truck Crops	42%	31%	33%
Protea	Not available	16%	44%
Fruit	5%	13%	24%
Other	20%	3%	8%
Average	22%	16%	27%

Secondary impacts of drought include the establishment of hardier invasive plant species, such as the deadly fireweed. Fireweed invades weakened pastureland and displaces grazing grass. The fireweed is a poisonous plant. If consumed by cattle, it may be fatal. In addition, drought-stricken agricultural lands have little or no vegetation; therefore, erosion and runoff will occur during large rainfall events and pollute receiving waters such as the coastal ocean areas.

7.3.3 CLIMATE CHANGE

As the ongoing discussion on global warming and climate change continues, there is growing certainty that the amount and frequency of rainfall will change, along with temperature, carbon dioxide, and ozone levels. These factors will influence agriculture in different ways as a long-term global event. The effects of these changes will be felt within the planning period, but the magnitude and extent are under debate and study. Climate change has a high probability to impact crop production, crop species, and market availability.

The University of Hawai'i at Mānoa Sea Grant study[38] summarizes the changes in precipitation from historical records, showing a decrease in rainfall over the last century. Observations also show that rainfall intensity and frequency has changed, with O'ahu and Kaua'i exhibiting less intense rainfall events and Hawai'i Island more intense rainfall events. Maui has shown a mix of rainfall intensity. Other pertinent observations are that droughts in recent decades have longer duration, and prevailing northeasterly trade winds have decreased in frequency over the last 40 years.

Due to the global nature of climate change, taking a narrow view of how it affects Hawai'i would be incorrect. The health of Hawai'i's agricultural industry depends on a thriving export market, and disruptions in the supply chains, fluctuations of the global economy, wars, and natural disasters have impacted Hawai'i's exports.

Climate change will impact the global agricultural industry. Because Hawai'i imports approximately 85-95 percent of its food and other agricultural commodities, climate change will impact food availability and prices. Short- and long-term agricultural water demand planning should not readily assume there will always be an adequate supply of food or other agriculture commodities from other domestic and global agricultural producers to import.

Therefore, given the State's policy of food security, import replacement, and overall sustainability, water supply and storage capacity will need to be increased to maintain and increase crop productivity and economic stability for farmers. This also increases the need to develop water sources to maintain productivity during longer dry/drought conditions, as well as through loss of surface water sources. In addition, climate change may change crop types and agricultural growing areas.

Because the water situation will change as climate change progresses, two (2) issues have been raised. First, the change in intensity and duration of rainfall needs to be accounted for by increasing water storage and upgrading distribution systems. Second, with increased drought, water demand for farms will increase to keep farm production at its current level, especially if

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[38] University of Hawai'i at Mānoa Sea Grant College Program, *Climate Change Impacts in Hawai'i - A summary of climate change and its impacts to Hawai'i's ecosystems and communities.* UNIHI-SEAGRANT-TT-12-04, June 2014.

the State's policies for a diversified agriculture industry, food security, and buying Hawai'i-grown products are to be met. Drought-level irrigation will increase the total water requirement of the crop, as stated in the water budget equations (normal rainfall + irrigation).

Aside from crop production, including livestock and aquaculture, the impact of climate change on the farm-to-market system is less clear. Current research is focused on crop production, but more research should be completed on:

- The supply and distribution chain;
- Farm inputs;
- Nutritional changes;
- Invasive species;
- Fisheries and aquaculture (marine and freshwater);
- Integration of non-food crops, other than agroforestry, into the analysis; and
- Mitigation options.

7.4 GOVERNMENT POLICIES THAT MAY AFFECT AGRICULTURE

In Hawai'i, government policies impact funding availability, as well as the creation of new rules and regulations. At this point in time, the following policies may influence agricultural production: sustainability and self-sufficiency, and import replacement. As these policies affect the agricultural production, there may be an impact on the overall agricultural water demand.

7.4.1 SUSTAINABILITY AND SELF-SUFFICIENCY

Although the State has studied and developed policies toward self-sufficiency, Hawai'i currently imports somewhere between 85 and 95 percent of its food, significant amounts of animal feed and fodder, and significant amounts of flowers and foliage. Although the goal of self-sufficiency[39] is considered

[39] **Self-sufficient** is the ability *to maintain oneself or itself without outside aid: capable of providing for one's own needs (a self–sufficient farm)* (http://www.merriam-webster.com/). Therefore, by definition, Hawai'i would not be able to import or to export agricultural commodities to be 100 percent self-sufficient. More so, the example of a self-sufficient farm is somewhat of an oxymoron because farms are commercial entities that export (sell, barter, or trade) their commodities to off-farm consumers. In addition, other inputs, such as

worthy by some, it is seen as unachievable by others. On the other hand, some farmers do consider sustainability[40] as an achievable goal.

A good first step toward achieving statewide sustainability is to develop a sustainable agricultural industry, both in resources and economics. The current movement is focused on developing sustainable food production, which is only one sector of the agricultural industry.

To be considered sustainable, the product must be marketable, have good and consistent quality, be reasonably priced, provide profitability to the farmer, and have a dependable supply to meet consumer demand. Inconsistent local availability of commodities leads to a dependency on imports. If farmers are to be expected to provide quality and consistent commodities, they must have an adequate and stable water supply for their crops, especially during severe weather conditions.

In addition to water supply and market, other factors, such as labor, cost of other inputs, transportation, and market trends, affect the agricultural industry. In 2010, SMS[41] studied the beef industry as it relates to self-sufficiency. Of 59,000 head of cattle sold to market in 2008, 43,000 were shipped out of state. In addition, the study computed that an additional 337,500 acres of grass pasture would be required to wean and raise 30,000 head of cattle for local consumption. The key issues are:

- The need for sufficient acreages with adequate water to be drought-resistant and irrigated to accommodate calf-to-cow finishing, and to provide a reliable and constant supply to the Hawai'i market;
- Lower slaughter and processing costs, which requires greater economies of scale (constant supply), and newer slaughter and processing facilities;
- A larger market and cost-effective, reliable transportation between islands; and

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seed/plantlets, fertilizer, feed, research, water, energy, tools, etc., are needed to cultivate a crop or grow livestock, and to operate and maintain the farm.

[40] **Sustainability** is "of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged" (http://www.merriam-webster.com).

[41] SMS, *Increase Food Self Sufficiency Report*, February 2010.

- Sufficient demand for grass-fed, locally grown beef that will command a higher price.

In 2012, the State of Hawai'i published *Increased Food Security and Food Self-Sufficiency Strategy.*[42] The purpose of the strategy was to increase the amount of locally grown food consumed by Hawai'i residents. The definition of food self-sufficiency is: ***the extent to which Hawai'i satisfies its food needs from local production.*** The strategy is addressed to state agencies and programs due to their statewide scope and geographic coverage and meant to be a living document. The strategy has three (3) objectives:

- Increase demand for and access to locally grown foods;
- Increase production of locally grown foods; and
- Provide policy and organizational support to meet food self-sufficiency needs.

The study found the following self-sufficient facts as of 2012:

- Hawai'i is close to self-sufficiency in the production of watercress, Chinese cabbage, mustard cabbage, green onions, and Asian vegetables. Local farmers also supply 75 percent of tomatoes, sweet potatoes, cucumbers, and sweet corn. Most lettuce and other vegetables are imported.
- Fruits such as watermelon, papaya, pineapple, and banana are mostly Hawai'i grown. Significant amounts of other fruits are imported.
- Based on a 2007 report, 150 head of cattle are slaughtered weekly, accounting for about 6 percent of local consumption.
- Hogs and pigs grown in Hawai'i have been on a steady decline from 1970 to 2009.
- Hawai'i was self-sufficient in eggs in the 1970s with 240 egg farms; however, there are currently less than 100 egg farms operating in Hawai'i today.
- In the 1970s, Hawai'i was self-sufficient in milk with 120 milk operations, but currently there is only one (1) dairy operation.

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[42] State of Hawai'i, Office of Planning, Department of Business Economic Development & Tourism, *Increased Food Security and Food Self-Sufficiency Strategy*, in cooperation with the State of Hawai'i, Department of Agriculture, 2012.

The key will be to first make the agricultural industry economically sustainable. However, the recent cessation of sugar cane cultivation by HC&S on Maui and the closure of Hāmākua Springs on Hawai'i Island does not bode well for the future.

7.4.2 IMPORT REPLACEMENT

The theory of import replacement was discussed in 1953 (Philipp) to expand the output of Hawai'i's diversified agriculture industry. Philipp stated:

> ***A Challenge***
> *It is evident that many of Hawai'i's diversified agricultural industries show promise for expansion and that such expansion would materially strengthen Hawai'i's economy. To bring it about, men are needed with vision, enterprise, venture capital, and capacity for hard work.*
>
> *The expansion of the diversified agriculture of Hawai'i is a challenge to all the people of Hawai'i.*

The issues and improvements detailed by Philipp are similar to current issues. The key issues were as follows.

- Reduce Costs
    - Increase Labor Productivity
    - Better Management and Buying Practices
    - Larger Farms
    - Greater Diversification of Farms
    - Increase Functional Specialization on the Farm
    - Market Development

- Environmental Conditions
- Land and Water
    - Development of low-cost irrigation water
- Credit
- Research, Education, and Governmental Actions
- Agricultural Planning

In 2008, University of Hawai'i, College of Tropical Agriculture and Human Resources (CTAHR), and the HDOA released a paper on improving Hawai'i's food self-sufficiency.[43] It is noted that the importation of food allows for cheaper food costs and a greater variety of food. Although some are willing to pay more for Hawai'i-grown products, higher prices are typically due to substantial "mark-ups" by wholesalers and retail outlets. The study recognizes that Hawai'i will continue to import food, but there are benefits in purchasing and producing Hawai'i-grown food such as:

- Supporting the local economy keeps money flowing through our community;
- Maintaining health, as the nutritional content of locally grown food is often higher, since many vegetables begin to lose their nutritional value after they are picked;
- Producing and buying Hawai'i-grown products decreases the "food miles" involved in transporting food, thus reducing their carbon footprint; and
- Decreasing the risk of the importation of harmful invasive pests that could damage agriculture and natural resources.

The study concluded that doubling the consumption of Hawai'i-grown food products based on 2005 statistics (approximately 15-20 percent) would generate farm-gate value of $119 million, which would translate to $238 million in sales and $8.7 million in state tax revenue. This forecast assumed that there were available resources and infrastructure to double production.

7.5 LEGAL RULINGS AFFECTING WATER

Navigating law, water rights, and management in Hawai'i can be complex, expensive, and time consuming. Experience to date indicates that securing water rights for agriculture may often be beyond the means of individual farmers. Therefore, in addition to preserving and maintaining agricultural water infrastructure, a State commitment to assisting farmers in securing water for agricultural purposes through regulatory processes is essential for the preservation and protection of agriculture in Hawai'i.

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[43] Leung, Ping Sun and Matthew Loke, *Economic Impacts of Increasing Hawai'i's Food Self-Sufficiency*, CTAHR Cooperative Extension Service, EI-16, December 2008.

The law of water rights and management in Hawai'i is set forth generally in the General Water Resource Management Principles and Policies section of the Water Resource Protection Plan, prepared and adopted by the CWRM, and will not be repeated here. Instead, this section discusses significant cases decided by the CWRM and/or Hawai'i courts as they affect agriculture, as well as a few issues of especial relevance to agriculture.

7.5.1 MAJOR WATER CASES

Most of the contested cases before the Water Commission have entailed years of expensive litigation. Of the five (5) major cases discussed below, three (3) have directly involved water for agriculture. Two (2) of those three cases involved the last surviving sugar plantation in Hawai'i and its shutdown in 2016. In the third case, owners of large tracts of agricultural land bore the litigation costs instead of their lessee-farmers. As the transition from large-scale mono-cropping to smaller-scale diversified farming continues in Hawai'i, it is unlikely that individual farmers will have the ability to protect or obtain rights to water for agricultural endeavors through similar types of proceedings.

Waiāhole Ditch. For about 100 years, the Waiāhole Ditch system had been delivering water from streams in Windward O'ahu or from dikes in the Ko'olau Mountains to irrigate sugar cane and other crops in Central and Leeward O'ahu. In the early 1990s, O'ahu Sugar Company, the last sugar plantation on O'ahu, announced that it would cease operations. The announcement set in motion the first large contested case under the State Water Code (enacted in 1987), in which the Water Commission had the responsibility of balancing varying interests in water. Primarily, the conflict revolved around the potential for replacing sugar cane with diversified agriculture in Central and Leeward O'ahu, which would rely on the continued use of the Waiāhole Ditch system versus restoration of streams in Windward O'ahu.[44] The contested case took place as the transition from sugar to diversified agriculture was taking place, and the uncertainty about the availability of water affected the investments necessary for the transition and the speed with which the transition occurred.

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[44] Dike water in the Ko'olau Mountains, if not developed by the Waiāhole Ditch system, would feed Windward O'ahu streams through seeps and springs.

The Waiāhole Ditch contested case involved more than a dozen parties, a lengthy initial hearing before CWRM, two (2) remand hearings, and three (3) appeals to Hawai'i appellate courts. The case combined processes for amending interim instream flow standards (IIFS) for four (4) Windward O'ahu streams with applications for water use permits for users of Waiāhole Ditch water in Central and Leeward O'ahu. Commenced in 1993, the case was finally concluded in 2010. Diversified farmers interested in farming the former sugar lands with water from Waiāhole Ditch included part-time vegetable and herb farmers on less than one (1)-acre plots, a 40-acre banana farm, highly professional growers of vegetable crops and landscape plants, and multinational seed companies. Most of these farmers, however, did not bear the costs of the contested case proceedings (which, conservatively, must have run into the millions of dollars); instead, the large landowners, interested in retaining the value of their lands for agriculture, bore most of the burden of the years of contested case proceedings. In the end, roughly 13 MGD was allocated for uses in Central and Leeward O'ahu, and roughly 16 MGD was restored to Windward streams.

Probably the most significant outcome of the Waiāhole Ditch case was the Hawai'i Supreme Court's articulation of the public trust doctrine and public trust uses of water. The public trust doctrine says that some resources are so important to public interest that no individual (person or company) can own it and do with it as the individual pleases. Instead, these resources are "owned" in common by all, and government must have the authority to make sure it is used for the public good. Only in very rare instances is the government allowed to abdicate this authority.

Furthermore, because of the importance of the resource to the public interest, the government has a duty to ensure that the resource will continue to be available for generations to come. On the other side of the argument:

> *"The water resources trust also encompasses a duty to promote the reasonable and beneficial use of water resources in order to maximize their social and economic benefit to the people of this state."*

The concept of public trust "uses" recognizes some uses as being of such importance to public interest that the State gives special protection to water resources to ensure those interests are protected. In the Waiāhole Ditch case, the Hawai'i Supreme Court identified (1) resource protection; (2) domestic uses; and (3) protection of traditional and customary native Hawaiian rights as purposes for having a water resources trust.

Significantly, the court did not identify agriculture as a public trust use. To the contrary, the court identified farming in Central and Leeward O'ahu as "for private commercial gains," which are not protected under the public trust. Notwithstanding being relegated to lower priority, there was sufficient water in the Waiāhole Ditch system to adequately provide for public trust uses and to meet the demands of agriculture. Today, diversified agriculture thrives on lands historically served by the Waiāhole Ditch.

Wai 'Ola O Moloka'i and Kukui (Moloka'i) Cases. Two (2) water use permit contested cases from the island of Moloka'i involved domestic uses of water for existing and planned housing and commercial developments. Although these cases did not involve agricultural use of water, at least two (2) significant rulings impact uses of water, including for agriculture.

One is that the Hawai'i Supreme Court added a fourth public trust use, namely, reservations of water for the Department of Hawaiian Home Lands (DHHL). Any proposed use of water requires a demonstration that such use will not adversely impact DHHL's need for water in the future.

Second, an applicant seeking an allocation of water has the burden of showing that the proposed withdrawal and use of water will not adversely affect traditional and customary Native Hawaiian rights. In meeting that burden, the applicant has the responsibility to discover what traditional and customary Native Hawaiian practices occur in the area, determine how those practices may be affected by the proposed withdrawal and use of water, and suggest mitigative measures to address negative impacts. When the applicant proposes the withdrawal of ground water, the impact on ground water discharge into the ocean, the consequent impact on the marine environment, and impact on traditional and customary Native Hawaiian gathering practices in the nearshore area must all be addressed.

Nā Wai 'Ehā. Nā Wai 'Ehā refers to the waters of the Waihe'e River, North and South Waiehu, 'Īao, and Waikapū Streams on the island of Maui. For nearly 150 years, the waters of Nā Wai ʻEhā had been diverted and transported through a complex ditch system, primarily to irrigate sugar cane, but also for other agricultural purposes and domestic uses. Additionally, the four (4) ahupuaʻa of Nā Wai ʻEhā were an area of extensive loʻi kalo and comprised the largest continuous area of wetland taro cultivation in the islands.

By 2004, when a petition was filed to amend the IIFS for the Nā Wai ʻEhā streams, the sugar cane lands that had been cultivated by Wailuku Sugar Company had been transitioned to urban-type developments and some diversified agriculture. However, HC&S still depended on this ditch system to irrigate about 5,000 acres of its 35,000-acre plantation. While kalo and other crops were being grown on the extensive kuleana lots within the watershed, the cultural renaissance sparked growing interest in opening more loʻi kalo and in restoring stream flows.

Unlike the Waiāhole Ditch case, where there was a enough water to generally accommodate different interests, meeting demands for Nā Wai ʻEhā water likely meant the reduction of existing uses and negatively impacting ongoing agricultural activities. This recognition that there would not be enough water to satisfy the various needs for water prompted the designation of Nā Wai ʻEhā as the first surface water management area in the state, meaning that each and every entity desiring to use Nā Wai ʻEhā water, whether the use had been ongoing for a century or more, or was proposed for a future project, had to apply for and obtain a water use permit issued by the Water Commission.

Before any surface water allocations could be made, the Water Commission had to first determine how much water would be available for off-stream uses. In other words, the Water Commission had to first decide on the IIFS for each of the Nā Wai ʻEhā streams before considering the applications for allocations of water. The IIFS was determined through a contested case proceeding, which included five (5) parties and was held between 2007 and 2010.[45] The Water Commission's decision, issued in 2010, was appealed and the Hawaiʻi Supreme Court remanded the case to the Water Commission on several issues. Although remand proceedings commenced, the parties mediated a

[45] Other consolidated proceedings included water use permits for small amounts of water from ground water sources and a waste complaint. These, and an unsuccessful attempt at mediation, occurred between 2004 and 2007.

settlement, thus truncating the process on remand. The Water Commission approved and adopted the mediated settlement in April 2014.

Subsequently, the Water Commission has been grappling with scores of claims of appurtenant rights to, and for water use permits for existing uses of Nā Wai ʻEhā water.

East Maui Irrigation System. The East Maui Irrigation System (EMI) is a highly complex ditch system that was constructed in phases between 1876 and 1923. It has continually served HC&S's Maui plantation and currently irrigates approximately 30,000 acres of HC&S's 35,000-acre plantation.

In 2001, Na Moku Aupuni o Koʻolau Hui (Na Moku) filed a petition to amend the IIFS for 27 streams in East Maui. EMI operates diversions on 23 of those 27 streams. At the time the petition was filed, the EMI system had been primarily used for sugar cane irrigation.[46] In other words, unlike the Waiāhole Ditch and Nā Wai ʻEhā situations, the request to amend the IIFS was not triggered by a transition in the use of lands or water.

Breaking from precedent set by the Waiāhole Ditch and Nā Wai ʻEhā cases, the Water Commission in 2008 and 2010 set new IIFS for 27 East Maui streams through public meetings, rather than contested case processes. In 2010, Na Moku petitioned for a contested case process to set the IIFS for these East Maui Streams. The petition was denied by the Water Commission on the basis that IIFS amendments were not subject to contested case proceedings, notwithstanding the fact that IIFS amendments for four (4) Windward Oʻahu streams and for the Nā Wai ʻEhā streams on Maui were established through contested cases. However, the Hawaiʻi appellate courts disagreed with the Water Commission, ruling that claimants of appurtenant or riparian rights to water, or those who claim that their traditional and customary Native Hawaiian rights may be affected by the IIFS decisions, had a right to have the IIFS determined through contested case proceedings. The CWRM Decision and Order on the IIFS was issued in June 2018.

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[46] The EMI system also provides water to the County of Maui for treatment for domestic potable uses and for its agricultural park.

7.5.2 WATER MANAGEMENT AREAS AND PERMITTING

Water rights and uses in Hawai'i are governed by the State Water Code, HRS Chapter 174C, and the common law. Water use is regulated by the Water Commission through a permit system in designated water management areas (WMA). Outside of WMAs, permits for water use are not required; however, extraction of the resource is regulated through well construction and pump installation permits (ground water), and stream channel alteration and stream diversion work permit (surface water).

HRS § 174C-41(a) explains the purpose of WMAs:

> ***"Designation of water management area.*** *(a) When it can be reasonably determined, after conducting scientific investigations and research, that the water resources in an area may be threatened by existing or proposed withdrawals or diversions of water, the commission shall designate the area for the purpose of establishing administrative control over the withdrawals and diversions of ground and surface waters in the area to ensure reasonable-beneficial use of the water resources in the public interest."*

In WMAs, any withdrawal, diversion, impoundment, or consumptive uses of water requires a water use permit (WUP) issued by CWRM (use of reclaimed wastewater is not governed by this provision). A permit must be obtained to continue uses of water that predated the designation of the WMA and before any new uses of water can occur. Obtaining a permit entails filing out an application that addresses several criteria.

Of significance to a farmer is the need to demonstrate that the amount of water being requested is reasonable and that the water will be used in an efficient manner. The CWRM utilizes the Irrigation Water Requirement Estimation Decision Support System (IWREDSS) developed by the University of Hawai'i College of Tropical Agriculture and Human Resources to benchmark the reasonable amount of water required for the type of crop planned for cultivation in the particular location. If the amount of water requested deviates from (exceeds) the IWREDSS benchmark, the applicant will have to proffer an explanation. Also, if a less efficient method of irrigation is proposed (e.g., overhead sprinklers instead of drip), the applicant will probably have to explain why the less efficient method is appropriate.

The applicant for a WUP also must demonstrate that use of alternative sources of water is not practicable or not in the public interest. For example, if an applicant proposes to use surface (stream) water for irrigation, the alternative sources discussion may state that reclaimed water is not appropriate for the type of crop grown, that municipal sources or desalinization would be too expensive, and that public policy favors using non-potable surface water, instead of potable ground water, for irrigation purposes.

Over the past several years, some farmers have experienced unexpected challenges associated with permitting in WMAs that do not arise in nondesignated areas. One issue has been the availability of "backup" water or a secondary source to meet agriculture water demand. In Hawai'i, where surface water flows fluctuate greatly over very short periods of time, reliance solely on surface water for irrigation needs can be risky. A solution is to have a "backup" well to supply ground water (which is generally more expensive) as a supplemental source when surface water is inadequate. However, in WMAs, where the amount of water permitted for a particular agricultural use is tied to water duties for particular crops in particular locations, a "backup" allocation would have the appearance of far exceeding the reasonable amount of water required, even though, in actuality, the "backup" water would be used only in the event that the primary source is inadequate to meet the permit allocation amount.[47] This issue would not occur in a nondesignated area, where the criteria for development of a backup well depends solely on availability of water at the well site and the mechanical characteristics of the well.

Applicants for WUPs have also had to address issues unrelated to the availability and protection of water resources. For example, in 2013, CWRM denied WUPS to two applicants requesting 6,000 gallons per day (0.006 MGD) and 8,000 gallons per day (0.008 MGD), respectively, for aquaculture

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[47] In 2012, the Water Commission failed to approve Monsanto's application for a backup ground water source for its Kunia, O'ahu, farm to be used in the event the Waiāhole Ditch system is unable to deliver Monsanto's allocated amount. Although ground water was available, the permit was denied on the basis that, "on the books," Monsanto would have a double allocation when the allocation of the ground water permit being requested was added to Monsanto's Waiāhole Ditch permit.

purposes.[48] The applicants were asked three (3) questions: 1) what would be the impact of the brine (the byproduct of desalinization would impact the nearshore environment, even though the amounts were small); 2) whether aquaculture ponds attract invasive birds that interbreed with native ducks, and 3) whether the proposed withdrawal of water would impact traditional and customary Native Hawaiian gathering practices in the nearshore area. Because the applicants could not answer these questions, the WUP applications were denied. Had these aquaculture farmers been in nondesignated areas, they would likely have to address these issues with other agencies, such as the Department of Health on the brine issue, and the U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources Forestry and Wildlife Division on the invasive bird issue. Unlike DLNR, these other regulatory agencies rely on their own expertise to advise on their decisions, whereas the Water Commission, in such areas, expects applicants to provide the expertise in order to obtain the WUP, even for small amounts, which adds to the financial burden of the farmers.

7.5.3 INTERIM INSTREAM FLOW STANDARDS

An interim instream flow standard (IIFS)[49] is a determination made by CWRM as to how much water must flow in a stream at a particular location. It is possible that one stream may have more than one IIFS, e.g., *x* MGD measured at Location A and *y* MGD measured at Location B. The IIFS for a stream could change depending on different times of the year, or even different times of the day.

The IIFS for any particular stream is the result of an analysis by the Water Commission as to the water requirements for a variety of public interests, both instream (such as for stream biota, recreational uses, scenic and aesthetic values, and hydropower) and offstream (such as for taro cultivation, agricultural irrigation, and domestic and municipal uses). There is no formula

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[48] WUP applications from Norman Rizk and Richard Foster for allocations of brackish water from the Kaluako'i aquifer on Moloka'i for aquaculture purposes.

[49] The Water Code makes a distinction between instream flow standards (sometimes referred to as "permanent") and interim instream flow standards, the former intended to be of a longer duration and, therefore, subject to a more extensive process for adoption. To date, however, every IIFS amendment has been subject to lengthy, fact-intensive proceedings, and no "permanent" IFS has yet been adopted for any Hawai'i stream by the Water Commission. Therefore, the discussion in this section will refer to IIFS only.

to apply. Necessarily, the Water Commission will have to exercise its discretion and judgment in setting IIFS.

For most of the 376 perennial streams in the state, the current IIFS is the "status quo" as of a specific date (generally between 1988 and 1992). This status quo IIFS is "diversion-based," in that it says that whatever diversions were in place at a particular date (effective date of the IIFS) could continue until either the IIFS was amended or the IIFS established.

Because most of the IIFS are diversion-based, any proposal to construct a new diversion or to modify an existing diversion to increase the amount of water diverted could trigger the need for an IIFS amendment.[50] The IIFS amendments to date, however, have been established pursuant to petitions filed by private entities. In all cases to date, IIFS amendments have been the subject of litigation conducted over periods of years.

New IIFS were established for Waiāhole, Waianu, Waikāne and Kahana Streams in Windward O'ahu through the Waiāhole Ditch contested case. Some water was restored to each of those streams, and, in the case of Kahana Stream, the existing diversions were closed, thus restoring Kahana as an undiverted stream.

IIFS proceedings for 'Īao, Waihe'e, Waiehu, and Waikapū Streams — collectively known as Nā Wai 'Ehā — were established in 2014 following settlement in a contested case proceeding. Some water was restored to each of the streams. In other words, less water is available for offstream uses under the 2014 IIFS. HC&S's January 2016 announcement that it would cease sugar cane cultivation and transition to diversified agriculture has triggered a reconsideration of the IIFS, but it is unlikely that more water would be made available for offstream users.

A petition was filed to amend the IIFS for 27 streams in East Maui. The Water Commission acted on the petition in two (2) phases, amending the IIFS for eight (8) streams in 2008, and the remaining 19 streams in 2010. Departing from the practice of amending IIFS through contested case proceedings, as was done in the Waiāhole Ditch and Nā Wai 'Ehā cases, the commission utilized

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[50] If the additional diversion amount is small relative to stream flows, an IIFS amendment may not be required.

a process of obtaining data through staff research, stakeholder input, and public testimony. In 2010, Na Moku challenged this process, and the courts ruled that Na Moku had a right to have the IIFS determined through a contested case process. Therefore, the Water Commission's 2008 and 2010 decisions have been vacated, and the IIFS for these East Maui streams are currently undergoing contested case proceedings.

7.5.4 APPURTENANT RIGHTS

Appurtenant rights are incidents of land ownership and are rights to the use of water utilized by parcels of land at the time of the original conversion into fee simple lands. The rights run with the land and are not personal. The measure of an appurtenant right is the amount of water utilized at the time of the Mahele, generally, but not exclusively, for taro cultivation. Once an appurtenant right is recognized and quantified, current use is not limited to its specific use at the time of the Mahele, but for uses on the parcel of land that are reasonable and beneficial.

In 1978, the Hawai'i State Constitution was amended by adding Article XI, section 7, which expressly protects appurtenant rights. The Constitution's protection of appurtenant rights is reflected in the 1987 State Water Code, HRS § 174C-63.

The CWRM has the legal authority to determine appurtenant rights pursuant to HRS § 174C-5(14). Until CWRM designated Nā Wai 'Ehā as a surface water management area, requests for determination of appurtenant rights have been rare. However, upon designation of the Nā Wai 'Ehā surface water management area, and the consequent requirement to obtain water use permits for use of Nā Wai 'Ehā water, approximately 100 appurtenant rights claims were filed for Nā Wai 'Ehā alone.

Proving the existence and the quantification of an appurtenant right to a parcel of land can be difficult. Documentation showing that the parcel, or a portion of the parcel, was being used as a residence or for cultivation at the time of the Mahele is essential, but oftentimes elusive. For example, documents often do not state what use was being made of the land at the time of the Mahele, but there may be circumstantial evidence, such as the existence of an 'auwai running through the parcel. The appurtenant rights claimant may also have to prove that the right was not extinguished.

Common misunderstandings arise about the relationship of appurtenant rights and kalo cultivation. Although kalo cultivation of a parcel of land at the time of the Mahele may be the source of the appurtenant right, the water associated with that right can be used today for any reasonable, beneficial purpose. Conversely, cultivating kalo today, even in a traditional manner, does not create an appurtenant right where none existed for that parcel at the time of the Mahele.

Another misconception about appurtenant rights is that it is a Native Hawaiian water right. As noted above, appurtenant rights were attached to parcels of land and, unless extinguished, continue to be attached to the parcel, regardless of change in ownership. The landmark *McBryde* case (*McBryde Sugar Company, Ltd. v. Robinson*, 54 Haw. 174 1973) involved the quantification of appurtenant rights claimed by two (2) large sugar plantations on Kaua'i.

A significant advantage of appurtenant rights is that the right is not lost due to nonuse and has some priority over other uses of water. For example, if a current owner chooses to start growing crops on a parcel of land that had not been cultivated for generations, but to which appurtenant rights are attached, the current owner should be able to obtain water for the parcel, even if it means that other cultivators in the area may have to reduce their water usage to accommodate the appurtenant right. Of course, this means that the farmer on a parcel of land without appurtenant rights to water faces insecurity that the amount of water being relied upon may be reduced by a late claim to appurtenant rights.

There is a distinction between an appurtenant right and the exercise of that right. The CWRM has the authority to determine whether an appurtenant right(s) attaches to a parcel of land and the amount of water that accompanies that right. How that right is exercised, however, is the responsibility of the right-holder. For example, water delivered through a ditch system (whether privately or government-owned) is not a right to use the delivery system. Use of the delivery system is generally through an agreement, whether formal or informal, between the right-holder and the operator of the system. If the operator of the system requires payment for use of the system, or decides to discontinue delivery, that dispute does not bear on the appurtenant right to water, and, generally, will not involve the CWRM.

Similarly, the existence of an appurtenant right does not automatically entitle the right-holder to divert water from the stream in exercise of that right without having first obtained the appropriate permit(s) for stream diversion works or stream channel alteration, both of which are administered by the CWRM.

7.6 PLANNING CONSIDERATIONS

The following topics were discussed during our interviews with farmers as important topics to be considered for agricultural water systems.

7.6.1 RELIABILITY

A reliable water supply throughout the year is necessary to provide a constant source of commodities to the marketplace, and to grow the agriculture industry. The water use will change as farmers change crops, planting regimes, and production volumes as the market changes, both locally and globally.

The use of monthly or annual rainfall averages does not provide accurate data to determine the water use per farm and will change yearly as rainfall and evapotranspiration changes per year.

Therefore, water reliability and backup systems need to be in place to assure farmers that the water requirements of their crops are to be met year-round, especially to promote increased sustainability for food and food security, but more so economic sustainability for the agriculture industry. Therefore, some of the larger farms have created back-up plans for water reliability by increasing storage, and/or having water supplies from different water systems. However, this increases the cost of production that will either be absorbed by the farmer or passed on to consumers of the commodity.

7.6.2 WATER PRESSURE AND FLOW

Water pressure is a key point in many systems. The design of the system must consider adequate water pressure requirements based on the irrigation systems used by the various farming operations. Ample water pressure is determined by farm layout, supply lines, and irrigation method (overhead, drip, flooding, etc.).

Water pressure is a concern in certain ditch and public water systems, especially those farms with long irrigation pipe networks. The issue is compounded as farmers water their crops simultaneously during the day. In one irrigation system, the private owner manages water demand by scheduling water irrigation times for each farm.

7.6.3 BEST MANAGEMENT PRACTICES

Water is also required for cover crops or alternative plantings. Although growing these crops increases water demand, it is deemed necessary as "best management practices" (BMP) for these lands. In addition to BMPs, the use of cover crops or mulch between planted rows minimizes weeds and conserves soil moisture.

Conservation tillage is any method of soil cultivation that leaves behind the previous year's crop residue (such as corn stalks or wheat stubble) before and after planting the next crop to reduce soil erosion and runoff. To provide these conservation benefits, at least 30 percent of the soil surface must be covered with residue after planting the next crop. Some conservation tillage methods forego traditional tillage entirely and leave 70 percent residue or more. Conservation tillage methods include no-till, strip-till, ridge-till, and mulch-till. Each method requires different types of specialized or modified equipment and adaptations in management.[51]

Some of the grain corn operators use technology to minimize their cultivation footprint. The use of global positioning satellite data allows companies to plant seeds in the same location over time. This practice minimizes the disruption of soil between planting rows.

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[51] http://www.mda.state.mn.us/protecting/conservation/practices/constillage.aspx. Accessed 2015.

7.6.4 OTHER WATER DEMAND

Agricultural water demand is typically focused on the irrigation aspects of farming. However, depending on the commodity, post-harvest processing can use as much as 30 percent of the total water demand. For certain commodities, farmers use agricultural water to eliminate or control pests, emulate growing habitats, and/or provide alternative growing conditions for commodities. For example, hydroponics and aquaponics, by their very nature, use water to create an environment for raising crops and aquatic life.

The high-water demand of wetland taro, for example, is required to keep the plant's temperature below 80.6 degrees Fahrenheit or 27 degrees Celsius. Lower plant temperature inhibits the growth of viruses. Some studies even suggest 25 degrees Celsius would be more effective. Of the hundreds of thousands of gallons of water per acre per day used in wetland taro production, only a small percentage is used for irrigation.

For Certified Nursery growers on the Big Island, water is used for the post-harvest treatment for pests. As much as 20 percent of a farm's water demand is used to produce a clean commodity for market. For example, to mitigate the movement of coqui frogs from their Certified Nurseries, exported plants are doused with a hot-water treatment for 20-30 minutes. The hot-water treatment has a 100 percent (100%) efficacy rating for coqui frogs and can also be used effectively against other pests, such as slugs.

For seed companies planting Genetically Modified Crops (GMOs), water is used to "flush" fields after harvesting, promoting the growth of any corn seeds remaining in the fields. The USDA permit condition[52] to allow for these plantings is as follows: *mandatory fallow period in which irrigation is provided to allow for germination of volunteers*.

During this mandatory fallow period, these "volunteers" are destroyed by seed companies as part of their permit condition. The destruction of volunteers is necessary to maintain the purity of the next crop to be planted in that field.

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[52] USDA permit to grow Genetically Modified Organisms, with Hawai'i Department of Agriculture concurrence.

Other uses of water for agriculture include, but are not limited to:

- Commodity preparation, cleaning, packaging, and processing (for example, one farmer interviewed uses 80,000-100,000 gallons per month, which is approximately 25-30 percent of the farm's irrigation requirements;
- Production area treatment (pest and disease control);
- Pre-shipment watering;
- Treatment of infested commodities;
- Pre-shipment treatment to remove pests;
- Cover crops to prevent soil erosion, replace nutrients, etc.;
- Worker requirements;
- Regulatory requirements; and
- Animal water requirements (animal husbandry).

7.6.5 SECONDARY SOURCE

As water is critical to the production of agricultural products, many water systems have backup plans to maintain water for crops in an emergency. These backup water sources may consist of wells, use of city/county water systems, and/or purchasing water from neighboring water systems. Most of these agricultural water systems rely on surface water diversions that will be the first to dry up in low rainfall periods. Therefore, as food security is a state goal, the development of long-term backup sources and/or long-term storage should be a priority.

CHAPTER 8
FORECAST ANALYSIS

The goal of forecasting is not to predict the future but to tell you what you need to know to take meaningful action in the present.

Paul Saffo

This section develops an agricultural water demand forecast for the next five (5) years, as required by HRS 174, and a long-range (20-year) forecast, as recommended in the AWUDP Framework. To develop the forecast, the analysis included a review of the forecast in the 2004 AWUDP, analysis of the collected water use and farm data, and analysis of past agriculture statistics.

Section 8.1 provides a review of the 2004 AWUDP forecasts. Section 8.2 discusses land-based forecast modeling, and Section 8.3 discusses using a linear regression model for the forecast. Section 8.4 discusses the recommended water demand forecast, and Section 8.5 lists limitations and constraints of the forecast.

8.1 2004 AWUDP FORECAST

The 2004 AWUDP based the forecast on three (3) planning considerations as follows:

- Potential new diversified crops, including crops consumed by Hawai'i's Asian market, other seed crops, and tropical specialty fruits;
- Niche markets and off-season market development, such as greens to Canada, local produce to local hotels during off-season months, aquaculture, and annual specialty events; and
- Import replacement crops that would focus on growing crops typically brought in from the continental United States or internationally.

To assess the land area needed within the planning period to increase agricultural production, the 2004 AWUDP analyzed three (3) factors: 1) annual population projections, 2) replacing imported fresh vegetables and fruits, and

3) maintaining past growth rates of farm values. The increased acreage was multiplied by 3,400 gpd/acre to determine the increased water demand. Table 134 summarizes the 2004 AWUDP results in five (5)-year increments.

Table 134
Island Summary of the 2004 AWUDP Forecasts
Additional Water Demand* (MGD)

County		Additional Acreage (acres)	Years 1-5	Years 6-10	Years 11-15	Years 16-20	Total
Kaua'i	Worst	3,545	3.27	2.80	2.89	3.09	12.05
	Best	14,198	13.15	11.20	11.55	12.36	48.27
O'ahu	Worst	2,226	2.08	1.75	1.80	1.93	7.57
	Best	8,939	8.43	7.00	7.23	7.73	30.39
Moloka'i	Worst	446	0.42	0.35	0.36	0.39	1.52
	Best	1,787	1.67	1.40	1.45	1.55	6.08
Maui**	Worst	891	0.84	0.70	0.72	0.77	3.03
	Best	3,544	3.29	2.80	2.89	3.09	12.05
Hawai'i	Worst	1,782	1.66	1.40	1.44	1.54	6.06
	Best	7,120	6.9	5.60	5.74	6.18	24.21
TOTAL	Worst	8,890	8.27	7.00	7.21	7.72	30.23
	Best	35,588	33.44	28.00	28.86	30.91	121.00

Notes: Worst Case - diversified agriculture would replace 10 to 20 percent of imported fruits and vegetables.
Best Case - diversified agriculture would replace 50 percent of imported fruits and vegetables.
* Based on water usage rate of 3,400 gpd/acre
** This does not include HC&S' 2016 decision to end sugar cultivation and transition to diversified agriculture. There will be an increase in diversified agriculture acreage but probably no increase in water demand.

Reference: 2004 Agricultural Water Use and Development Plan.

The population growth rate was based on DBEDT population forecasts and diversified agriculture historical growth rates obtained from the Hawai'i Agricultural Statistics (HASS). From 1982 to 2001, the 2004 AWUDP used an average growth for diversified agriculture between three (3) and five (5) percent annually.

To forecast the impact of replacing imported fruits and vegetables, two (2) scenarios were evaluated: 1) "Best case" and 2) "Worst case." The "best case" scenario was conservatively based upon the current percentage of the total market supply which could be met by local production. The analysis predicted the local production should be able to replace 40 percent of imported fruits and vegetables. For the "worst case" scenario, a review of studies by others on the growth of farming in the state showed that with status quo farming operations, local production would replace 10 to 20 percent of imported fruits and vegetables. Therefore, the analysis used the 10 percent growth rate to forecast future agricultural growth based on the replacement of imported fruits and vegetables. There was no analysis for other commodities, such as flowers, foliage, or meats.

8.1.1 DISCUSSION OF 2004 AWUDP FORECAST

According to the 2004 AWUDP, the increase in agriculture is not related to population growth, as Hawai'i imports 85 to 95 percent of commodities. In addition, industry growth is related to the national and global economy, as Hawai'i's agricultural industry exports many commodities. Therefore, a consideration in the 2004 AWUDP forecast was the import replacement program. Although this topic has been much discussed since 1950 or earlier, and has long been and continues to be a primary objective for agricultural growth in the state, there has not been significant growth in this area. A similar state objective is sustainability, which has lost ground since 1970. According to the 2012 State of Hawai'i Food Security study, Hawai'i has lost a significant portion of its dairy and egg production when compared to 1970.

One of the factors used in the 2004 forecasts was an agricultural growth rate between three (3) percent to five (5) percent. Using the methodology indicated in the 2004 AWUDP, the economic value of "diversified agriculture" shows an actual average annual growth rate of approximately 6.5 percent from 2000 to 2011. This is a slightly larger growth rate than the growth rate used in the 2004 AWUDP.

The economic impact of agriculture in local markets has not been studied comprehensively, but pricing data shows a demand for Hawai'i-grown products. A 2012 study for HDOA-Plant Quarantine Branch on import replacement showed that Hawai‘i-grown commodities were marked up higher by retailers and wholesalers when compared to non-Hawai‘i products.

The study found that wholesalers are buying O‘ahu-grown commodities at prices similar to those of imported commodities (free-on-board/freight-on-board (FOB) Honolulu). However, the study also shows that the markup by wholesalers and retailers are greater for Hawai‘i-grown commodities (35 percent) versus the markup on imported commodities (27 percent). The study also concluded that the larger farms on O‘ahu have changed the market for diversified agriculture in the state, making O‘ahu more self-sufficient in produce items such as tomatoes, bananas, watermelons, etc.

8.2 LAND-BASED MODEL ANALYSIS

Historically, Hawai‘i’s sugar industry developed its agricultural water systems to irrigate land for agricultural production, sugar cane transport, and mill water. The water demand per acre was typically consistent if the crop was the same. At the peak of the monocrop industry in 1920, approximately 250,000 acres were in production, with an average diversion of 800 MGD of surface water and about 400 MGD of groundwater.

Therefore, traditional water demand forecasts were based on a water demand rate per acre multiplied by the number of acres of agricultural land. Over time, the amount of land used for agriculture decreased from 1,969,345 acres in 1987 to 1,926,971 in 2012, based on the agriculture-designated lands by the State of Hawai‘i Land Use Commission.

A steeper decline in agriculture land area is shown in the USDA National Agricultural Service Statistics (NASS) census data provided in Table 135. The data shows a significant decrease in land used for crop cultivation, from 499,504 acres in 1959 to 174,042 acres in 2012. During this same period, the area of irrigated cropland decreased from 141,179 acres to 81,813 acres.

Table 135
Specific Agriculture Data from Census of Agriculture - Hawai'i[53]
(land area in acres)

Year	Land in farms	Total Cropland	Harvest Cropland	Other (a) Cropland	Irrigated Cropland
1959	2,461,454	499,504	176,410	155,755	141,179
1982	1,957,501	346,113	155,960	156,596	145,982
1992	1,588,843	293,371	136,431	119,330	134,338
1997	1,439,071	292,107	100,094	150,179	76,971
2002	1,300,499	211,120	109,461	65,119	69,194
2007	1,121,329	177,626	103,120	51,013	58,635
2012	1,129,317	174,042	99,031	67,473	81,813

Note: a) Other Cropland includes land that have cover crops, soil-improvement grasses that are not harvested or pastured, crops that have failed, summer fallow croplands, or are idle.

Utilizing a land-based forecast, the NASS data shows a decrease in irrigated farmland, which translates to a decrease in total water demand. Assuming a water demand rate of 3,400 gpd/acre, the daily water demand would have been 278 MGD in 2012, compared to 480 MGD in 1959. In this model, the availability of water should not be an issue, as the amount of water required for irrigation of agricultural lands had dropped by about one-third (1/3) since sugar was king, and about one-half (1/2) since 1959. Past studies have reported water withdrawal quantities in the state to be as high as 1.2 billion to 1.9 billion gallons per day for surface and groundwater combined.

The correlation of land area to water demand is also complicated by the assumption that all crops have the same water demand and one water demand rate is sufficient to compute the total agricultural water demand in the state. Based on the survey data from 2014, a correlation of water demand to land area was performed. The correlation coefficient[54] computation returns

[53] USDA, National Agricultural Statistics Services, "Census of Agriculture - State Data," various years

[54] Reference: https://support.office.com/en-us/article/CORREL-function-995DCEF7-0C0A-4BED-A3FB-239D7B68CA92

the correlation coefficient of the two number arrays and determines the relationship between two properties. In general, the closer the correlation coefficient is to one (1), the better the correlation between the two properties. The correlation coefficient of an array of x-values and an array of y-values is computed using the following equation.

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

Where: $\bar{x}$ *and* $\bar{y}$ are the sample means for the array of x-values and the array of y-values, respectively.

Table 136 shows the correlation factor[55] between irrigation water demand to cultivated land area. The analysis shows fair to good correlation between irrigation water demand and land in areas growing crops with similar water demand rates, such as leafy vegetables. This correlation increases significantly for these farming areas if outlier data points are removed. In farming areas which have a diverse mix of crops, the correlation is poor to none.

The farm survey provided data on land use on the farm. Table 136 presents the percentage of the total farm area being used for cultivation at the time of the survey. There are numerous reasons for lower utilization of farmland for cultivation, such as, but not limited to, farm structures, access roads, unusable land such as steep slopes and rock outcrops, lack of water, lack of labor, market demand, crop rotation, and farmer preference. The areas that produce mainly vegetable and produce crops have an average cultivated area of 48 percent of the total parcel acreage, demonstrating the 50 percent crop rotation (planted area) land factor.

[55] The correlation factor shows the relationship or correlation between two properties. The closer the correlation factor is to 1, the closer the relationship is between the two properties.

Table 136
Correlation of Land Area to Water Use
(based on cultivated area)

Location	No. of Farms Used to Compute Correl. Factor	Average Cultivated Area/ Total Area (all farms)	Correlation Factor (land area vs. water use)
Kula	7 of 9	29%	0.98
	9 of 9		0.74
Kaua'i	7 of 7	41%	0.92
Pāhoa	12 of 15	80%	0.90
	15 of 15		0.67
Mililani	9 of 10	59%	0.90
	10 of 10		0.61
Kahuku	9 of 11	44%	0.89
	11 of 11		0.75
Moloka'i	9 of 9	60%	0.88
Waimānalo	11 of 11	71%	0.16
Pana'ewa	11 of 11	89%	0.05
Keāhole	10 of 10	75%	-0.19

Therefore, as there is a diversity of crops today, and crops may change to meet consumer demand or for economic reasons, the water demand computation by land area may not provide an adequate value for the overall agricultural water demand. Each agricultural water system will have a water demand rate based on the climate, soil, crop diversity, and farming techniques used by the individual famer.

In addition, the survey and NASS data shows that land should not be a limiting issue for the development of agriculture. The limited farm survey completed in 2014 showed that the cultivated acres in certain locations are at or below 50 percent of the total farm acreage. The NASS data shows a steady decrease in cropland since 1959. In addition, other forms of gardening and agriculture increase the growing acreages beyond traditional agricultural lands. These include aquaculture, greenhouse agriculture, rooftop gardens, vertical planting, and indoor agriculture.

One of the ongoing issues regarding production and water use on agricultural lands is the so-called "gentleman farms" that take advantage of agricultural water rates and reduced fees and taxes but do not add or have limited value to the farm gate value. The study did not attempt to classify these gentleman farms, as the acreages per farm are usually small (2 acres or less) and beyond the scope of this study.

8.3 LINEAR REGRESSION MODEL ANALYSIS

The regression model forecasts are based on the NASS economic data to determine future agricultural industry trends. A linear regression analysis based on historical agriculture farm gate values is shown on Table 137. The linear regression was computed using three (3) ranges of historical data, and three different trend lines emerged. The three (3) ranges of historical data were as follows: 1) from 1978 to 2012; 2) from 1992 to 2012; and 3) from 1997 to 2012. It was assumed that 1) the growth of production is related to economic forecasts; 2) the increase in production will translate to an increase in the number of acres in active cultivation, thus increasing water demand; and 3) land availability is not a constraint, although for the individual agricultural water systems, land may be a growth constraint.

When using the statistics, it is important to note that the pineapple industry was listed as a separate sector and not included in the diversified agriculture statistics prior to 2007. As the pineapple industry has diminished, the pineapple industry value was included into the "diversified agriculture" totals in 2007. Therefore, it caused a step function increase in the diversified agricultural statistics.

The three (3) forecasts are shown on Exhibit 38, based on three (3) different trend years: 1) using the data from 1978 to 2012 results in an average annual future growth rate of 0.5 percent per year; 2) using the data from 1992 to 2012 results in a future growth rate of 1.2 percent a year; and 3) using the data from 1997 to 2012 results in a future growth rate of 1.2 percent per year. The average growth rate of the three (3) scenarios is 0.6 percent. The 1978-2012 data set analysis takes a longer view of the historical trend in Hawai'i's agriculture, in a modern-day setting. The 1992-2012 data set starts at a time when agriculture was declining, with most of the sugar mills closed and the pineapple industry winding down.

Table 137
NASS Farm-Gate Value Statistics

YEAR	VALUE	PERCENT CHANGE
1978	$419,251,000	--
1982	$558,608,000	33.24%
1987	$609,740,000	9.15%
1992	$552,054,000	-9.46%
1997	$496,935,000	-9.98%
2002	$533,423,000	7.34%
2007	$513,626,000	-3.71%
2012	$661,347,000	28.76%

The 1997-2012 data set uses a low point in the agriculture value as the starting point, thus providing a higher trend line and reflecting the growth of the diversified agriculture industry.

As the agriculture industry grows, the secondary or trickle-down effect would be approximately two (2) billion to three (3) billion dollars to Hawai'i's economy. The 68-sector 2005 Hawai'i State Input-Output Model provides a tool to estimate the potential economy-wide impacts for agricultural growth. Based on the model, an increase in $1 of farm-gate value would generate $2.06 in sales, $0.54 in earnings, and $0.078 in state tax revenue.[56] The model also estimates that for every million dollars of farm-gate sales, approximately 25 new jobs will be created.

[56] ibid (Ping Sun and Loke, Matthew, 2008)

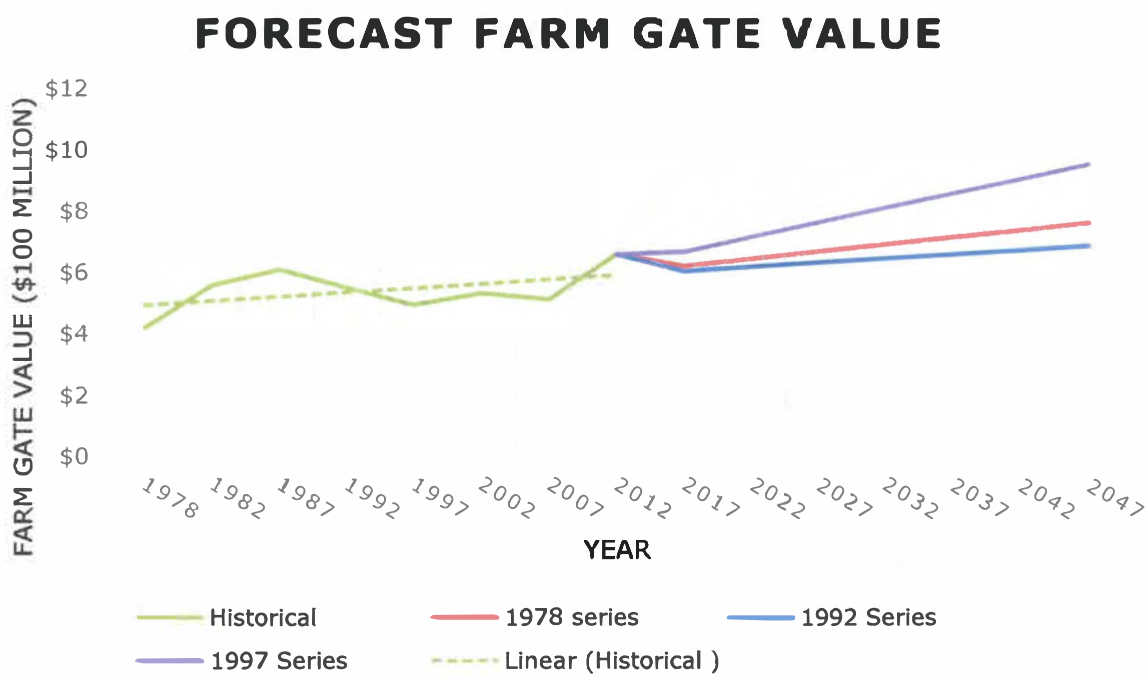

Exhibit 38. NASS Farm Values-Based Economic Forecasts

8.4 RECOMMENDED AGRICULTURAL WATER FORECAST

One of the goals for this AWUDP is to ensure the agriculture water infrastructure has the capacity to support the growth of diversified agriculture. Therefore, the recommended forecasts are developed to support these goals. The economic value of the agricultural systems is highlighted in a report of the Wahiawā Irrigation system (2008). The report states that the area serviced in the Poamoho, Hale'iwa and Waialua areas had an estimated farm-gate value of $37.7 million in 2007. The estimated total impact, both direct and indirect, was computed to be $85.2 million dollars for the same year. These economic values were based on 6,400 acres of agricultural lands, of which 55 percent are under cultivation. The report also indicated that additional water supply may allow increased use of the remaining 45 percent of fallow leased lands (6,400 acres). In addition, portions of the 1,715 acres of land currently not leased could be under production if tenants and water were available.

The potential for increased production from an agricultural water system is provided in the report by Mink and Yuen for the Lower Kula Water system. The report surveyed farmers in the Lower Kula area to assess the potential of greater productivity if water supply was increased and reliable. The results of the survey are shown in Table 138.

Table 138
Estimated Potential for Increased Production
Increased Water Supply and Reliability
Lower Kula (2003)[57]

Crop	Would Grow Additional Acres of Same Crop	Would Grow Acres of New Crop	Would Expect Higher Yields
Truck	79%	75%	88%
Protea	46%	23%	77%
Fruit	20%	36%	71%
Other	33%	33%	72%
Average	45%	42%	77%

8.4.1 POTENTIAL LAND USE

Based on the analyses of agricultural water systems, the agricultural land use for each system was computed and is summarized in Tables 139 to 142. The tables present the amount of land used for field crops, other crops, and grazing. "Other crops" include all diversified agricultural crops, such as vegetables and truck crops, which are not considered field crops or grazing. In addition, the potential area available for increased farming activity is based on an analysis of the land use within the service area, as well as discussions with water system managers. The potential agricultural areas do not include areas that would require a new agricultural water system.

[57] Mink and Yuen, Inc. & Associates, *Kula Stormwater Reclamation Study, Task 1, Existing Conditions Report*, September 2011.

The 2004 AWUDP estimated the amount of unused agricultural lands in the 13 studied systems to be 35,588 acres, or approximately 40 percent of the total acreage of the 13 systems. This study shows that there are approximately 29,870 acres available for agriculture, however, some of the systems did not report available agricultural lands. Based on the GIS and the inventory studies, there is approximately 114,360 acres of the total service area not used for agriculture. However, these unused areas include unusable lands, such as roadways, gullies, etc. If a factor of 40 percent (similar to the 2004 AWUDP) is used, the estimated available land area is 45,744 acres.

Table 139
Agricultural Land Use by System, Kaua'i County

Irrigation System	Field Crops (acres)	Other Crops (acres)	Total Cultivated (acres)	Grazing (acres)	Total Active (acres)	Available Land (acres)
Kaloko	0	61	61	945	1,006	---
Stone Dam	0	8	8	51	59	---
Kalihiwai	184	189	373	10	383	245
Anahola	107	409	516	2,039	2,555	1,454
Upper and Lower Līhu'e	229	608	837	1,636	2,473	---
Upper and Lower Ha'ikū	205	591	797	2,142	2,939	---
Waiahi-Kuia Aq. and Kōloa-Wilcox	889	1,501	2,390	2,871	5,601	---
Olokele	7,472	934	8,406	1,385	9,791	---
East Kaua'i	---	---	1,530	4,380	5,910	---
Kaua'i Coffee	---	---	3,900	490	4,390	2,319
Kekaha	6,517	---	6,517	0	6,617	2,626
Kōke'e	---	---	---	1,192	1,192	992
TOTAL			25,335	17,141	42,916	7,636

Table 140
Agricultural Land Use by System, Oʻahu

Irrigation System	Field Crops (acres)	Other Crops (acres)	Total Cultivated (acres)	Grazing (acres)	Total Active (acres)	Available Land (acres)
Oʻahu Ditch	4,602	4,313	8,915	1,590	10,505	4,595
Opaeʻula and Kamananui	158	1,575	1,733	2,719	4,452	---
Former Galbraith Lands	0	993	993	0	993	0
Kahuku (HDOA portion)	0	198	198	0	198	0
Waimānalo	---	---	810	110	920	470
Waiāhole	---	---	4,000	---	4,000	3,290
TOTAL			16,649	4,419	21,068	8,355

Table 141
Agricultural Land Use by System, Maui County

Irrigation System	Field Crops (acres)	Other Crops (acres)	Total Cultivated (acres)	Grazing (acres)	Total Active (acres)	Available Land (acres)
Upper Kula	---	---	400	250	650	420
Lower Kula	---	---	1,252	---	---	1,253
East Maui	---	---				---
West Maui/Pioneer	---	---	6,320	---	6,320	2,610
Molokaʻi	---	---	2,670	680	3,350	6,382
TOTAL			10,642	930	10,320	10,665

Table 142
Agricultural Land Use by System, Hawai'i County

Irrigation System	Field Crops (acres)	Other Crops (acres)	Total Cultivated (acres)	Grazing (acres)	Total Active (acres)	Available Land (acres)
Ka'ū	6,353	1,850	8,203	28,087	36,290	---
Kohala	0	1,064	1,064	4,823	5,884	---
Kehena	0	7	7	9,178	9,185	---
Lower Hāmākua	---	---	310	3,670	3,950	1,714
Waimea (Upper Hāmākua)	---	---	740	570	1,310	1,000
TOTAL			10,324	46,328	56,619	2,714

8.4.2 RECOMMENDED FORECAST FOR AWUDP UPDATE

Due to Hawai'i's dependency on an aging water infrastructure, future agricultural production will depend on the operational capacity of these water systems. Therefore, the AWUDP updated forecasts are based on three (3) forecast scenarios of the ability of the water system to deliver water and capture currently untapped agricultural lands for cultivation. The three (3) forecast scenarios are 1) no action, 2) maintained water systems, and 3) large capital investment.

For the maintained and large capital investment scenarios, an agricultural growth rate of 0.6 percent per year is assumed. Unfortunately, a lack of agricultural statistics hampers the development of an accurate baseline for agricultural water demand in 2015. Therefore, a computed baseline was prepared based on available irrigation system data and spatial analysis from irrigation systems. For irrigation systems without reported flow, the baseline was computed using a water demand rate for the crops. In this calculation, water demand rate for field crops was 7,800 gpd/acre, and diversified crops were 3,900 gpd/acre (assuming field rotation). The computed baseline for water at the source is based on 50 percent system loss. The estimated forecast for the next 20 years is presented in Table 143.

The forecast demand is provided by county (Table 144). As this is a planning-level baseline, the following assumptions were used for the three (3) scenarios. In addition, water demand for East Maui and Wailuku irrigation systems are not included due to recent legal proceedings and business decisions. All forecasts are unconstrained and assume that new sources/intakes will be developed when needed and includes total active and available land acreages from each of the counties in the preceding tables.

8.4.2.1 No-Action Scenario

The agricultural water systems will continue to age and deteriorate unless action is taken. Over time, the systems will become unusable and prone to catastrophic failures. There are examples of how neglected systems have deteriorated and been abandoned, such as the Lower Anahola ditch system. Revitalizing such deteriorated systems would be challenging and costly, especially when compared to a system that has been regularly maintained. In this scenario, no resources are used to maintain or rehabilitate the systems.

Table 143
Water Demand Forecast at Source
(MGD)

	FORECAST		
	2020	**2025**	**2035**
Statewide (Estimated 2015 baseline demand 651 MGD)			
No Action	488	326	0
Maintained	672	693	734
Increased Investment	956	1,027	1,170

Table 144
County Water Demand Forecast at Source
(MGD)

	FORECAST		
	2020	**2025**	**2035**
KAUA'I COUNTY (Estimated 2015 baseline base demand – 250 MGD)			
No Action**	187	112	0
Maintained	257	265	281
Increased Investment	319	329	349
HONOLULU COUNTY (Estimated 2015 baseline demand -145 MGD)			
No Action**	109	73	0
Maintained	150	154	163
Increased Investment	215	219	229
MAUI COUNTY* (Estimated 2015 baseline demand – 116 MGD)			
No Action**	87	58	0
Maintained	119	123	130
Increased Investment	203	206	214
HAWAI'I COUNTY (Estimated 2015 baseline demand – 141 MGD)			
No Action**	106	71	0
Maintained	146	150	159
Increased Investment	219	273	379

Note: * Maui County does not include HC&S and West Maui Irrigation systems
** No Action is based on a linear decay, actual failure is unpredictable

Therefore, under the no-action scenario, the future water flow reduces to zero (0) during the planning period. Table 143 shows the zero (0) flow condition statewide, and Table 144 shows the zero (0) water flow by county. Agricultural production will decrease significantly and be dependent on available rainfall to maintain crop viability.

The loss of agricultural production due to the failure of agricultural water systems will be detrimental to the industry, and that impact is compounded with the loss of HC&S and Hāmākua Springs. This loss will have a significant impact on the state's economy and socioeconomic factors. The state's goals for food security, diversified agriculture, and import replacement would not be realized. In addition, the potential environmental impacts would include an increase in fallow lands that leads to increased runoff into the ocean and onto reefs, and an increase in fugitive dust; changes to the aquifers benefiting from agricultural irrigation; and higher probability of increased urbanization of agricultural lands.

8.4.2.2 Maintained Water System Scenario

In the **maintained water system scenario**, funding is invested into water systems to maintain current flow rates and system capacities. In this scenario, the systems which are currently water limited will not be able to increase production, as water quantity cannot be increased. The systems which have surplus agricultural lands and sufficient water supply will be able to increase agricultural production until their water capacity is reached.

In this scenario, the agricultural farm gate value growth will follow the forecast growth trends based on historical data (Section 8.3) of less than one percent (1%) per year. Therefore, the corresponding agricultural water demand will slowly increase to approximately 734 MGD, as shown on Table 143. In addition to minimal growth in diversified agriculture and continuing deterioration of the system, the long-term concerns are as follows:

- Increased maintenance costs to provide consistent flow and labor costs;
- Inadequate water storage for long-term droughts;
- Systems will continue to deteriorate, and larger projects and increased funding may be needed in the long term;
- Need for additional water sources is required due to lack of rainfall (drought conditions) and climate change; and
- The current system distribution losses (non-revenue water) will remain or worsen.

8.4.2.3 Large Capital Investment Scenario

In the **large capital investment scenario**, the State of Hawai'i and private owners fund improvements to the public and private irrigation systems. The funding will improve the agricultural water systems beyond the 20-year forecast period. As stated by a system manager, "*We would like the system to last another 100 years*."

The forecasts shown in Table 143 show a slight growth rate in the first five years as the systems are being renovated (planning, design, and construction). Those systems with smaller projects may increase water demand and production in the latter part of the first five-year period. Those systems with larger projects and the new water system will be completed within the second five years or in the future. The significant increase in water availability will allow for increased water demand and agricultural production in available agricultural lands within the systems and the new systems proposed to be developed. In the latter portion of the forecast (15 to 20 years), the growth rate will slow as additional lands are occupied and will follow the historical growth rates for the industry.

The "Increased Investment" scenario incorporates the increase of grass-fed beef production and increases land area for this purpose. For the cattle industry, increased water supply may allow for 1) increased acreage for "finish grazing" or irrigated (managed) pastures to increase production of grass-fed beef[58], and/or 2) increased feed production if system owners are willing to open current non-irrigated land areas identified to feed and crop production. Based on the anticipated increase in water supply in the agricultural systems, the twenty-year forecast is shown on Table 143 as approximately 1,170 MGD.

The large influx of funds will provide for reliable water delivery to the farms, as well as a higher probability to increase agricultural production within the agriculture water system's service area. The increase in production may be as high as double the current production value in a few systems. To allow this potential to be realized, the funding would improve the system components in several ways:

[58] This forecast was not intended to meet the full requirement of grass-fed beef.

- Construction of the short-term (first five years) projects to address overdue maintenance issues, and in some cases long-term solutions to current issues;
- Increase of water storage capacity; and
- Increase water intakes and water sources.

The 1,170 MGD is an unconstrained agricultural water demand and based on increased grass-fed beef and diversified agricultural crops within the existing and new water systems. Historical reports on agriculture water demand indicates that the sugar industry used surface and groundwater between 1,200 MGD to 1,900 MGD. Due to the new policies, rules and regulations, and water-demand decisions, the 1,170 MGD agricultural water demand may not be achievable.

8.5 LIMITATIONS AND CONSTRAINTS

The change in the growth scenario will be impacted by the growth of diversified agriculture and other farming factors such as availability of labor, new pests and diseases, costs of producing commodities that compete with mainland import prices, costs for fertilizer, increased regulations, encroachment by non-agriculture uses, and increased environmental pressures.

The forecasts provide a guide to water demand, as the actual demand varies based on farmer practices, soil type, crop type, intensification, diversity, climate, politics, transportation costs, fuel and energy costs, market variability, consumer demand, etc. Due to the lack of accurate flow readings, the forecast is based on an estimated planning level baseline. As stated above, system owners and operators should analyze their systems to provide a more accurate forecast of agricultural water demand.

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CHAPTER 9
DEVELOPMENT PLAN

It is recommended that in order to encourage the expansion of diversified farming in the interest of the State's economy, the Legislature give consideration to some form of subsidization for irrigation projects where financial help is needed. Existing statutes require repayment of principal and interest for capital costs of construction which, in some instances, may make the cost of irrigation water too high for economic farming.
Hawai'i Water Authority

The HRS 174C requires the inclusion of a master irrigation inventory plan. Two (2) of the required elements of the master irrigation inventory plan are 1) a five (5)-year program to repair the systems, and 2) a long-range plan to manage the systems. To fulfil these elements, a development plan is presented which acts as a roadmap for addressing agricultural irrigation infrastructure maintenance and provides an impetus to discuss future management strategies for each system.

These elements are vital for the current maintenance of the agricultural water systems, as well as their envisioned future use and potential expansion. As many of Hawai'i's agricultural water systems have been in use for nearly a century, their continued operation is the goal of system managers. However, many of these systems have not been continuously maintained throughout their transition from plantation agriculture to diversified agriculture. Therefore, the systems require major maintenance projects to remove overgrowth, repair components, rebuild intakes, and reestablish user access. In addition, the current rules and regulations for reservoirs, dams, and in-stream flow have significantly altered many systems' water storage capacity and supply. These new rules and regulations affect the amount of water supplied to the farms, especially during drought conditions, and may impede the rehabilitation or growth of the affected system.

This Chapter presents:
- Section 9.1 the five (5)-year (short-term) CIP cost by county;
- Section 9.2 the potential management strategies; and
- Section 9.3 funding options.

9.1 FIVE-YEAR CAPITAL IMPROVEMENT PROGRAM

The five (5)-year (short-term) CIP is comprised of projects identified during the inventory assessment for the individual water systems.[59] Most of the CIP consist of urgent projects to maintain or increase water to agricultural users. The CIP cost beyond five (5) years were difficult to determine or will be determined based on the preliminary engineering and/or planning studies proposed in the short-term.

The short-term CIP is described in detail in the analysis for each agricultural water system, and Tables 145 to 149 provide summaries of the CIP cost. Table 145 summarizes the statewide CIP cost of approximately $168 million (one hundred sixty-eight million dollars) for the inventoried systems. Tables 146 to 149 summarize the CIP costs for short-term improvements for each system by county. The projects range from feasibility studies for two (2) new systems on Hawai'i to upgrading open-ditch systems to new pipeline networks.

Table 145
Statewide CIP Summary by County
(2018 dollars)

COUNTY	2018-2023
KAUA'I	$45,010,000
HONOLULU (O'AHU)	$39,185,000
MAUI	$53,800,000
HAWAI'I	$29,475,000
TOTAL	**$167,470,000**

[59] The CIP was determined with the assistance of the system managers and/or owners. Capital improvements are funded by the owners. Typically, government owned systems are funded by public funds and privately owned systems are funded by private funds.

Table 146
CIP Summary for Kaua'i County Irrigation Systems
(2018 dollars)

System	2018-2023
Kalihiwai System	$220,000
Anahola DHHL System	$13,600,000
Kōloa-Wilcox Ditch (Lāwa'i (A&B) Portion)	$1,350,000
East Kaua'i System	$19,240,000
Kekaha/Kōke'e	$11,000,000

Table 147
CIP Summary for O'ahu Irrigation Systems
(2018 dollars)

Project	2018-2023
O'ahu Ditch (Wahiawā, O'ahu, Ito, and Helemano)	$8,360,000
Kahuku Irrigation System	$4,370,000
Galbraith Lands System	$17,000,000
Waiāhole Irrigation System	$5,730,000
Waimānalo	$4,800,000

Table 148
CIP Summary for Maui County Irrigation Systems
(2018 dollars)

Project	2018-2023
Upcountry Maui	$200,000
Moloka'i	$9,160,000
Planning and preliminary design for New Lower Kula Irrigation System	$45,000,000

Table 149
CIP Summary for Hawai'i County Irrigation Systems
(2018 dollars)

Project	2018-2023
Kehana Ditch	$7,250,000
Waimea Irrigation System	$6,700,000
Lower Hāmākua Ditch	$ 6,150,000
Planning study for new irrigation system(s) in South Kohala and Kawaihae area	$1,500,000
Planning study(s) for new irrigation system for Ahualoa, Waimea, and Lālāmilo areas	$1,500,000

9.2 LONG-RANGE PLAN FOR SYSTEM MANAGEMENT

Currently, the existing management of the state's agricultural water systems is provided by various entities, depending on each system's ownership. The HDOA-ARMD manages state-owned systems, with CIP funding provided by state bond funds and operational and management fees collected for water use. The ADC oversees and assists in the management of water systems which are transitioning from the plantation era to diversified agriculture. These systems are managed by ADC or private entities, and funding derives from state funds, private funds, and fees collected for water use. The private water systems are owned and managed by private owner(s).

The intent of this section is to propose strategies, ideas, etc. for consideration in the management of the irrigation system. It is not the intent of this section to determine or modify the management style, organization, etc. for each system. During the inventory and interview considerations, programs which have been implemented or are being pursued by others, or long-range CIP projects were discussed. The following section briefly presents these suggestions and programs by stakeholders for long-range plans.

9.2.1 CONSIDERATIONS

The following considerations presented themselves during the interview and inventory process.

- These water systems are currently a century old. Their age tends to increase operational and maintenance costs and require major improvements to extend lifespan. These improvements are seen in the five (5)-year development plan and shown in the water forecasts.

- The water systems were designed for monocrops such as sugar and pineapple, which may have longer maturation times and water requirements than other crops. Depending on the variety, sugar cane matures between 12 to 24 months, and pineapple fruits in approximately 18 months. On the other hand, diversified agriculture crops, such as leafy greens, mature between two (2) to four (4) months.

- During the plantation era, water resources were adequate for plantation needs and uses. However, in today's regulatory environment, there are limits to the amount of water available for agriculture.

- Honolulu Board of Water Supply rates governing the use of potable water are increasing. For example, if a farmer uses 7,000 gallons per acre per day, by 2023 the farmer's water rate may increase approximately $66 per month per acre from 2018.

- State of Hawai'i's goals, which require an increase in agricultural production, crop diversity, and economics, include:

    - Diversifying the economy;
    - Sustainability and self-sufficiency; and
    - Support of diversified agriculture.

9.2.2 LONG-RANGE DEVELOPMENT PLAN PROJECTS

The following are suggested projects which may help system owners and managers oversee and best use their limited resources. These are considered long-range programs, but the programs can be implemented as necessary by the system owner at any time.

Additional CIP Projects. The short-term projects included feasibility and/or preliminary engineering for new water systems in Lower Kula, Maui; the Honoka'a-South Kohala region, Hawai'i; and the North Kohala-South Kohala region, Hawai'i. If these feasibility studies and preliminary engineering studies have positive results, there may be requests for CIP in the medium- to long-term (5 to 20 years) periods.

In addition, future projects being discussed as long-term projects include the use of pipelines to replace open ditch systems. These improvement projects may be performed in any of the open ditch systems, and will be dependent on various conditions, including funding. The pipelines will reduce maintenance costs and non-revenue water loss. It is recommended that such replacement projects focus on areas with high potential for debris, sediment, and rock accumulation, as well as areas that are difficult to access for maintenance. However, the pipelines will retard any net water gains (water seeping into the system) which may occur in unlined ditch systems.

Reclaimed Water. Reclaimed water from WWTP can be considered for use on agricultural lands for certain irrigation purposes, subject to government regulations. In Hawai'i, the Department of Health classifies recycled water based on the level of treatment. The higher level of treatment, the broader the irrigation purposes — with fewer restrictions on use. From an economic perspective, the distribution of reclaimed water limits where the reclaimed water is used. It would be preferable to have the agricultural area down gradient (slope) from the WWTP. As most WWTPs are near the coast, there is limited potential applications for use of reclaimed water on agricultural lands.

The only irrigation system considering the use of reclaimed water is the Galbraith Land Irrigation System. This system plans to use reclaimed water from the Wahiawā WWTP, due to the irrigation systems location downgradient from the Wahiawā WWTP.

Automated Water Management Solutions. These systems offer a wide range of capabilities and are offered as customizable packages for the agricultural water system owner, operator, and end user. Comprehensive solutions have the potential to develop complex water budgets based on agronomic factors and monitoring. Benefits include reduced water consumption, manpower requirements for irrigation, and fertilizer expenses. In addition, these systems offer features such as, but not limited to:

- Water accounting and billing solutions;
- Automated real-time climate data, such as daily evapotranspiration and rainfall rates;
- Alerts and messages on system performance, including leak detection;
- Statistical agronomic factors per crop; and
- Multiple irrigation scheduling.

Monsanto has installed automated irrigation systems on their farms in Hawai'i and reduced their water use by 20 percent (2014).[60] Their system is set up to be operated and monitored remotely. Monsanto is researching other technologies that have the potential to reduce crop irrigation demand. These systems may not be cost-effective for smaller individual farms but may be beneficial to water system owners and managers.

Distribution System Losses. Long-term projects should include distribution system loss studies. Distribution system loss is one component of non-revenue water. For these projects, the distribution system loss should be focused on the seepage loss through open ditch systems which are unlined or have lining which is failing. Currently, it is estimated that the distribution system loss is between 50 percent to 65 percent. However, each system is different, so it is recommended that a study be performed for each system and includes alternatives to reduce distribution system loss.

Invasive Species Eradication/Restoration. Invasive species have impacted irrigation systems through overgrowth, root damage, and clogs. Ironwood trees (*Casuarina*) are introduced plant species which are considered pests, or invasive plants. These trees, particularly their needles, increase

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[60] Personal communication, May 29, 2014.

maintenance problems for irrigation system operators, as the needles fall into the ditch and create “ironwood needle mat” clogs. The clogs reduce water flow and/or create overflow conditions, which lead to erosion and damage to ditch walls. Ditch managers clear these "mats" frequently, sometimes every day, to maintain flow. In addition, these trees prevent understory growth, which increases erosion with stormwater runoff.

Other invasive trees encountered during the site visits include eucalyptus (paper bark) and albizia. The albizia and eucalyptus are creating dams in natural waterways, reducing storage capacity of reservoirs, and blocking access roadways. Therefore, the eradication of invasive species, especially invasive tree species, will prevent further deterioration of irrigation systems and reduce maintenance costs for ditch managers. To mitigate erosion, projects should require replanting of the affected areas with applicable native species or non-invasive introduced species.

Water Storage. Certain systems need more water storage to increase reliability and stabilize flow. An analysis of each water system would determine the amount and location of such storage. As most of these systems are dependent on one (1) or two (2) surface water sources, it makes them very rainfall dependent, and the variation of flow by actual month can fluctuate greatly.

One example is at the Kehana Ditch. Over a period of several months, USGS measured the flow rate in the system. The flow varied from a low of zero (0) MGD to a high of 29.7 MGD. The average monthly flow during the measurement period also had a large fluctuation, ranging from four (4) MGD to nine (9) MGD.

One option to increase water storage capacity is to use underground storage systems. These underground storage units have been used on the continental United States as a method to control stormwater runoff. These units can be constructed under other manmade structures and do not pose flood hazards to downstream areas. However, large underground storage systems are costly and require large excavation quantities for installation.

Stormwater Recharge. Given the restrictions and safety concerns of dams, large-scale water storage projects would be difficult and costly to construct.

However, as long-term droughts and heavier rainfall events are forecasted to continue, large water storage systems will be required to ensure the continued productivity of the agricultural industry, especially if sustainability and a healthy agricultural industry are goals of the state. One option is to re-consider aquifer recharge to store large quantities of water.

Hawai'i's aquifers are naturally occurring and can store large amounts of water for long periods of time. In 1959, Hawai'i Water Authority reported that HC&S's groundwater recharge program was performed using excess surface water from HC&S's extensive water ditch system. During an eight (8)-year period (circa 1959), HC&S diverted an average of 2,400 million gallons of surface water a year to recharge the groundwater aquifer. The most effective method at that time was to fill unlined reservoirs above their normal operating levels to increase the rate of seepage. This recharge program was performed with the assistance of the Territorial Commissioner of Public Lands, as Territory-owned waters were involved.

9.2.3 POTENTIAL MANAGEMENT STRATEGIES

The following are potential strategies which may be applicable to certain irrigation systems within the state.

9.2.3.1 Operation and Maintenance

Acquire easements or agreements. One of the obstacles for the plantation systems transferred to private ownership is the lack of maintenance easements or right-of-entry agreements to the irrigation system or water source. Without routine access to the system, portions of the system fall into disrepair or become clogged with debris, which limit the water flow to the users. In addition, clogs cause erosion of the ditch wall and increase ditch repair costs.

Reduce non-revenue loss. Implement measures to reduce non-revenue water (system losses), especially in open ditch areas, unlined reservoirs, or in leaking facilities. However, the seepage from unlined reservoirs is one of the better methods to perform aquifer recharge.

Establish operation and maintenance agreements. The system owner could consider establishing an agreement with farmers served by the system to assist in its maintenance and operation. These agreements should be associated with lower water use fees or reduced future rate increases. This option is limited to privately owned water systems, and not applicable to water systems owned or could be owned by the state.

Research technological management options. Due to the high cost of labor, system owners or managers should research the applicability of new technology to provide:

- Automated water management systems;
- Inspection and operations; and
- Water-use management.

Promote increased agriculture. To meet the state's goals and provide economic stability to the agriculture industry, the following concepts should be explored:

- Increase production in existing agricultural area systems by constructing new distribution systems or new water intakes;
- Develop new distribution systems for new production areas;
- Develop long-term strategies to maintain, secure, and increase water resources to IAL lands and agricultural lands, in general;
- Secure current water allocations for the long term; and
- Assist the agriculture industry to transport Hawai`i-grown commodities to intrastate, interstate, domestic, and international markets.

9.2.3.2 Education and Outreach

Education is the key to water demand management, both for new and continuing farmers. Education topics should include water demand, water conservation, new technologies, and management strategies. State agencies should organize educational sessions with the following proposed strategies:

- First-generation farmers on irrigation and water use;
- Technology for improving water resource management and leak prevention; and

- Agricultural water roundtable, annually, for system owners to discuss agricultural issues and work on common solutions.

9.3 FUNDING

The statewide short-term improvements have repair and rehabilitation costs of approximately $168 million (2018 dollars). Most of the projects are to repair or re-open portions of the agricultural water system. Interviews with system managers demonstrate that they share a common goal of supplying water to agricultural interests for the long term. However, daily operations and maintenance budgets generally are not enough to perform all necessary repairs, as costs are rising for labor, overhead, material, and equipment. The stakeholders also state that there is no single commodity group within Hawaiʻi's agricultural industry that can afford to maintain or develop an agricultural water system.

As many of the state's water systems are almost a century old, they require significant improvements and major maintenance projects to continue long-term delivery of water to farms. This section discusses some funding options that may assist system owners.

Tax-exempt general obligation bonds may be used to fund the CIP owned by the State of Hawaiʻi. Private entities may utilize State of Hawaiʻi taxable general obligation bonds as CIP funding. Special purpose revenue bonds from the State of Hawaiʻi also may be used to fund CIP for agricultural enterprises serving IAL.

There is also the "private activity bond," which has an annual ceiling based on a percentage of the annual state ceiling for each calendar year, as follows:

- State - 50%;
- City and County of Honolulu - 37.55%;
- County of Hawaiʻi - 5.03%;
- County of Kauaʻi - 2.41%; and
- County of Maui - 4.01%.

9.4 CONCLUSION

Agriculture is an essential component for the state to achieve its goals of sustainability and a diversified economy. The agricultural industry relies on these water systems to deliver inexpensive water to meet and expand agricultural production. By supporting, maintaining, improving, and expanding these water systems, the agricultural lands have the potential to maximize agriculture production to meet state and export market demands.

However, other factors, such as the aging farmer population, new rules and regulations, and social concerns placed on agriculture, will increase the costs and risks of farming. These systems have the potential to service approximately 41,200 acres of quality agricultural land for various crops, including the most productive agricultural lands in the state. Most of the crops in these agricultural water systems are food-related crops, which support the state's goal of food sustainability.

The investment into these agricultural water systems is the key to provide adequate water to continue to grow diversified agriculture. As the saying goes, *... without water there is no agriculture ...*, which is the reason these agricultural water systems were originally constructed — and why they need to be maintained for another 100 years.

CHAPTER 10
REFERENCES

No race can prosper till it learns there is as much dignity in tilling a field as in writing a poem.

Booker T. Washington

1. AquaTechnex, LLC, "*Kalihiwai Reservoir Bathymetry Study*," Prepared for James Bray, Summer 2009.

2. Bohle, Mylen Bohle and Garry Stephenson, "*Irrigating Pastures - Small Farms Programs*," Oregon State University Extension Service Crook County, Summer 2007, Vol. II No. 2.

3. Brewbaker, James L., "*Corn Production in the Tropics, The Hawaii Experience,*" College of Tropical Agriculture and Human Resources, University of Hawai'i, 2003.

4. Casale, Rich, "Pasture Management," Livestock and Land Program, http://www.ncrcd.org/files/4613/8082/3073/Pasture_Management.pdf.

5. Cheng, Chui Ling, U.S.G.S, "*Measurements of Seepage Loss and Gains, East Maui Irrigation Diversion System, Maui, Hawaii*," Open-File Report 2012-1115, 2012.

6. FAO, "*Crop Evapotranspiration - Guidelines for computing crop year, Chapter 6, Etc- Single Crop Coefficient (Kc),*" http://www.fao.org/docrep/X0490E/x0490e0b.htm.

7. Fares, Ali, "*Irrigation Water Requirement Estimation Decision Support System (IWREDSS) to Estimate Crop Irrigation Requirements for Consumptive Use Permitting in Hawaii*," Commission of Water Resources Management, August 2013.

8. Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013, "*Online Rainfall Atlas of Hawai'i,*" Bull. Amer. Meteor. Soc. 94, 313-316, doi, 10.1175/BAMS-D-11-00228.1.

9. Giambelluca, T.W., X. Shuai, M.L. Barnes, R.J. Alliss, R.J. Longman, T. Miura, Q. Chen, A.G. Frazier, R.G. Mudd, L. Cuo, and A.D. Businger. 2014. Evapotranspiration of Hawai'i. Final report submitted to the U.S. Army Corps of Engineers—Honolulu District, and the Commission on Water Resource Management, State of Hawai'i.

10. Gingerich, S.B., Yeung, C.W., Ibarra, T.N., and Engott, J.A., "*Water Use in Wetland Kalo Cultivation in Hawai'i*," U.S. Geological Survey Open-File Report 2007-1157, 2007.

11. Godbey, Robert Carson, Special Deputy Attorney General, *"Report of the Independent Civil Investigation of the March 14, 2006, Breach of Ka Loko Dam,"* January 2007.

12. Google Earth V 7.1.2.2041, (October 7, 2013) State of Hawai'i, 2014 to 2015, http://www.earth.google.com.

13. Hawai'i Water Authority, "*Water Resources in Hawaii*," March 1959.

14. Hawaiian Irrigation Company, Limited, "*Report of Hawaiian Irrigation Company Limited for the Twelve Months Ending December 31, 1917*," February 1918.

15. Hawai'i Irrigation Authority, *"Irrigation Requirements and Available Water Resources, Waimanalo Irrigation System,"* Territory of Hawai'i, 1956.

16. Hawaiian Sugar Planters' Association, "*Plantation Archives, Register of the McBryde Sugar Company, Eleele, Kauai, 1896-1960*," Accession # 84-02, October 1987.

17. Hilo Engineering, Inc., "*A Report on the Investigation and Evaluation of Upper Hamakua Ditch, Waimea, South Kohala, Island of Hawaii*," Prepared for the State of Hawai'i, Department of Land and Natural Resources, Division of Water and Land Development, June 1986.

18. Howitt, Richard, Duncan MacEwan, Josue Medelin-Azuara, Jay Lund, and Daniel Sumner; "*Economic Analysis of the 2015 Drought for California Agriculture;*" UC Davis Center for Watershed Sciences, ERA Economics, and UC Agricultural Issues Center; funded by California Department of Food and Agriculture, University of California-Davis, and California Department of Water Resources; August 17, 2015.

19. Intergovernmental Panel on Climate Change, "*Meeting Report of the IPCC Expert Meeting on Climate Change, Food, and Agriculture*," Dublin, Ireland, World Meteorological Organization, Geneva, Switzerland, July 2015.

20. Izuka, Scot K., "*Effects of Irrigation, Drought, and Ground-water Withdrawals on Ground-Water Levels in the Southern Lihue Basin, Kauai, Hawaii*," Scientific Investigation Report 2006-5291, U.S. Department of the Interior, U.S. Geological Survey, County of Kaua'i, 2006.

21. Izuka, S.K., Oki, D.S., and Chen, C., "*Effects of Irrigation and Rainfall Reduction on Ground-water recharge in the Lihue Basin, Kauai, Hawaii*," Scientific Investigation Report 2005-5146, U.S. Department of Interior, U.S. Geological Survey, 2005.

22. Jacobs, James J., "*Hawaii's Water Resources, Sources, Demands, and Issues*," Hawai'i Institute of Tropical Agriculture and Human Resources, University of Hawaii, May 1983.

23. Jurassic Kahili Ranch webpage, http://jkr-kauai.com/, accessed 2015.

24. Kalihiwai Reservoir webpage, http://kalihiwaireservoir.info/, accessed 2015.

25. Kaua'i Historical Society, "*Finding Aid to the Kilauea Sugar Plantation Company Records, Kilauea, Kauai, Hawaii, Records 1877-[1932-1950s]-1971,*" http://kauaihistoricalsociety.org/wpcontent/uploads/2014/12/manuscript_01.pdf.

26. Klingebiel, A. A. and P. H. Montgomery, "*Land-Capability Classification,*" Soil Conservation Service, Agriculture Handbook N. 210, September 1961.

27. Kohala Watershed Partnership, "*Kohala Mountain Watershed Management Plan*," Draft December 2007.

28. Ladd Family, "*Ladd & Company, Koloa Plantation - Hawaii's First Sugar Plantation,*" http://www.laddfamily.com/files/Koloa Plantation/Hawaii.htm, accessed April 2, 2015.

29. Leung, Ping Sun and Matthew Loke, "*Economic Impacts of Increasing Hawaii's Food Self Sufficiency*," CTAHR Cooperative Extension Service, El-16, December 2008.

30. Lyon, "*Limited Archaeological & Historical Survey, Anahola Reservoirs Improvement Project*," September 4, 2014.

31. MacLennan, Carol A., "*Sovereign Sugar, Industry and Environment in Hawaii*," University of Hawai'i Press, 2014.

32. Melrose, Jeffery, Ryan Perroy, and Sylvana Cares, "*Statewide Agricultural Land Use Baseline 2015,*" University of Hawai'i at Hilo, Spatial Data Analysis and Visualization Research Lab, 2016.

33. Minnesota Department of Agriculture, http://www.mda.state.mn.us/protecting/conservation/practices/constillage.aspx, accessed 2015.

34. Mink and Yuen, Inc. & Associates, "*Kula Stormwater Reclamation Study, Task 1, Existing Condition Report*," Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

35. Mink and Yuen, Inc. & Associates, "*Kula Stormwater Reclamation Study, Task 1, Existing Condition Report*," Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

36. Mink and Yuen, Inc. & Associates, "*Kula Stormwater Reclamation Study, Task 2, Drought Mitigation Resource Analysis Report*," Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

37. Mink and Yuen, Inc. & Associates, "*Kula Stormwater Reclamation Study, Task 3, Alternatives Identification and Analysis Report*," Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

38. Mink and Yuen, Inc. & Associates, "*Kula Stormwater Reclamation Study, Task 5, Final System Development Assessment Report*," Central Maui Soil and Water Conservation District and USDA Natural Resources Conservation District, September 2011.

39. Nakahara, Richard H., "*Water Use in Hawaii, 1980*," United States Geological Survey, in cooperation with the State of Hawai'i, Department of Land and Natural Resources, June 1984.

40. Oceanit, "*Water Loss Estimation from Waiahole Ditch System*," December 2009.

41. Philipp, Perry F. "*Diversified Agriculture of Hawaii*," University of Hawai'i Press, 1953.

42. Rieth, Timothy, and Alex Morrison, "*An Inventory Survey of the Proposed Kawaihae Road Bypass Corridors, Kawaihae 1 & 2, Ouli, Lalamilo, and Waikoloa Ahupuaa, South Kohala, Hawaii Island*," January 2010.

43. Pennstate Extension, *Grass-Fed Beef Production*, the Pennsylvania State University, 2018.

44. R.M. Towill, "*Final Environmental Assessment/Finding of No Significant Impact, Kunia Agricultural Park, Kunia, Oahu, Hawaii*," State of Hawai'i, Department of Agriculture, 2015.

45. Schneekloth, J. and A. Andales, "*Seasonal Water Needs and Opportunities for Limited Irrigation for Colorado Crops,*" Colorado State University Extension, Fact Sheet No. 4.718, revised September 2009.

46. Shade, Patricia J., "*Estimated Water Use in 1990, Island of Kauai, Hawaii*," U.S. Geological Survey, in cooperation with the Kaua'i County Department of Water, Water-Resources Investigations Report 93-4180, 1995.

47. SMS, "*Increase Food Self Sufficiency Report*," February 2010, http://www.4aghawaii.org/files/48042347.pdf.

48. Southichack, Mana K, "*Wahiawa Irrigation System, Economic Impact Study*," State of Hawai'i, Department of Agriculture, Agricultural Development Division, Market Analysis and News Branch, November 21, 2008.

49. State of Hawai'i, Board of Agriculture, Minutes of the Board of Agriculture - (Draft) February 24, 2015, downloaded http://hdoa.hawaii.gov/wp-content/uploads/2012/12/BOA-minutes-2.24.15.pdf, August 25, 2015.

50. State of Hawai'i, Department of Agriculture, "*Protecting the Livestock Industry in Hawaii, Report to the Legislature of the State of Hawaii, in response to 2007 House Concurrent Resolution No. 170, SD1 and Senate Concurrent Resolution No. 192*," December 2007.

51. State of Hawai'i, Department of Agriculture, USDA National Resources Conservation Service, Hāmākua Soil and Water Conservation District, and Mauna Kea Soil and Water Conservation District, "Watershed Plan and Final Environmental Impact Statement, Lower Hamakua Ditch Watershed, Hawaii County, Hawaii," September 1999.

52. State of Hawai'i, Department of Hawaiian Home Lands, "*Anahola Regional Plan, Kamalomalo'o, Anahola, Moloa'a*," June 2010.

53. State of Hawai'i, Department of Land and Natural Resources, *Lalamilo Water System, South Kohala, Revised Environmental Impact Statement,* March 1980.

54. State of Hawai'i, Office of Planning, Department of Business Economic Development & Tourism, "*Increased Food Security and Food Self-Sufficiency Strategy*," in cooperation with the State of Hawai'i, Department of Agriculture, 2012.

55. Sustainable Resources Group Intn'l, Inc, "*Kilauea Irrigation Water Engineering Design and Monitoring Study*," County of Kaua'i, Office of Economic Development, Final Report, June 2009.

56. The Garden Island, "*Island History - The McBryde-Koloa War*," December 25, 2009.

57. Towill, R.M., *'Final Environmental Assessment, Kilauea Agricultural Park, Kilauea, Kauai, Hawaii, Tax Map Key, (4) 5-2-004:099*," Prepared for the County of Kaua'i, Office of Economic Development, June 2011.

58. U.S. Department of Agriculture, Soil Conservation Service, *"Land-Capability Classification,"* Agriculture Handbook No. 210, September 1961.

59. U.S. Department of Interior, Geological Survey, "*Surface Water Supply of Hawaii, 1948 - 1949,"* prepared in cooperation with the Territory of Hawai'i, Geological Survey Water-Supply Paper 1155, 1952.

60. U.S.G.S., Surface – Water Monthly Statistics for the Nation, (http://waterdata.usgs.gov/nwis).

61. University of Hawaiʻi at Mānoa Sea Grant College Program, "*Climate Change Impacts in Hawaii - A summary of climate change and its impacts to Hawaii's ecosystems and communities.*" UNIHI-SEAGRANT-TT-12-04, June 2014.

62. Wilcox, Carol, "*Sugar Water, Hawaii's Plantation Ditches,*" Honolulu, University of Hawaiʻi Press, 1996.

63. Wilson, Juan, "*Hub of the water wheel SUBHEAD: The Kaloko Reservoir is the nexus of water control in the Koolau Moko affecting several Ahupuaa,*" Island Breath, 5 June 2009.

64. Wilson Okamoto & Associates, "*Revised Environmental Impact, Kahuku Agricultural Park,*" State of Hawaii, Department of Agriculture, 1984.